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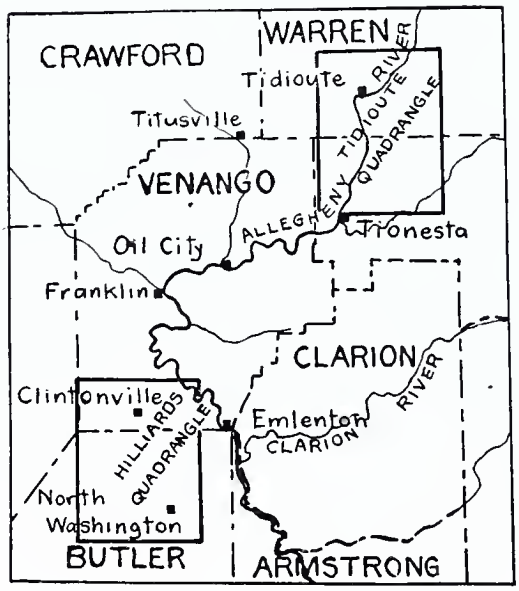
GEOLOGY OF THE OIL AND GAS FIELDS OF THE HILLIARDS QUADRANGLE

(ADVANCE REPORT)

by

R. E. SHERRILL and L. S. MATTESON



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GEOLOGY OF THE OIL AND GAS FIELDS OF THE HILLIARDS QUADRANGLE, PENNSYLVANIA

(Advance Report)

by

R. E. Sherrill and L. S. Matteson

INTRODUCTION

The Hilliards quadrangle is in western Pennsylvania, and occupies a part of northern Butler and southern Venango counties. It covers about 226 square miles—17.25 miles north and south by 13.1 miles east and west.

Oil and gas pools occupy about 58 square miles in this quadrangle. The oil recoverable by primary production methods is nearing exhaustion in all these pools, and many formerly productive areas have been abandoned, leaving most of the oil in the sands. Unless repressuring, water-flooding, mining or other secondary recovery methods are applied, most of the oil now in these sands will remain there permanently and detailed subsurface geological information is essential to successful application of these methods. The purpose of the survey of which this is an advance report was to determine as minutely as possible the subsurface distribution, character, thickness, structure and content of the sand bodies. This quadrangle was selected as one of the areas in which to make a detailed survey because the southern terminus of the Upper, or Tidioute-Bullion, oil belt and a part of the Lower, or Butler-Clarion, oil belt lie in it. It was felt that in addition to supplying a geological tie between these oil belts and to preserving the subsurface data still available, this survey might assist in the selection of areas for additional oil recovery, in the development of these areas, and possibly, in locating new shallow and deep pools.

Every available well record was collected, each well located on a four inch to one mile topographic map and the well elevations determined with an altimeter or alidade. Where possible, samples of the sands and of the oil were collected. A few core analyses were collected but very little coring has been done in this quadrangle. The known production limits of the sands were drawn on the maps and all available verbal information on the sands assembled. The locations of isolated dry holes and of undrilled areas were determined as thoroughly as time and data permitted, but doubtless many dry holes of which little or no evidence now exists were not located. About 3,000 well records were collected, of which 2,160 were located and the elevations determined. This work was done by R. E. Sherrill, assisted by L. S. Matteson and T. H. Jones during parts of the field seasons of 1936, 1937, and 1938.

We regret that it is impossible to mention here each company and individual who aided in this survey. We especially desire, however, to express appreciation to T. W. Phillips Gas and Oil Co., South Penn Oil Co., Manufacturers Light and Heat Co., Peoples Natural Gas Co., Pittsburgh Oil and Gas Co., President Oil Co., Lincoln Oil Co., Franklin Trust Co., Clarence Strance, Clyde Jamison, J. M. Christy, D. L. Baird, Lyle and Carl Hilliards, D. L. Hindman, Mark Graham, S. Y. Ramage, Sr. and Jr., Carl Smith, H. Hoffman, S. L. Cokain, Russell Foster, Lon Riddle, G. K. Anderson, J. Witherup, R. H. Lamberton and the many other leaseholders who cooperated to the fullest extent. Without the support and information supplied by the operators the report could not have been completed.

TOPOGRAPHY AND DRAINAGE

This quadrangle lies within the drainage basins of the Allegheny and Beaver rivers. The divide between these drainage basins lies relatively close to the Allegheny River, which crosses the northeastern part of the quadrangle in a narrow, gorge-like valley. The Scrubgrass and other creeks tributary to the Allegheny flow in steep-sided valleys, but Slippery Rock Creek, which flows westward to the Beaver, is in a flat-bottom marshy valley. This flat-bottom valley is a sand- and clay-filled glacial lake. The upland surface of the quadrangle is an undulating plateau, mostly between 1,400 and 1,500 feet above sea level. The lowest point in the quadrangle is about 890 feet above sea level and the highest about 1,590. The part of the quadrangle lying northwest of a general line from Wick to Bullion was glaciated during the Pleistocene period.

SURFACE STRUCTURE

Regional. Structurally, the Hilliards quadrangle is in the northwestern part of the Appalachian foreland. This foreland lies west and north of the closely folded and faulted Appalachian Mountains. It is a broad, gentle, spoon-shaped synclinorium, whose long axis extends in a northeasterly and southwesterly direction, and whose lowest part is in northwestern West Virginia.

The southeastern part of this foreland basin is characterized by a series of rather prominent northeast-trending anticlinal and synclinal folds. In the northwestern part of the foreland the folds have so diminished in magnitude and regularity that their detection and tracing is best accomplished by determining elevations on selected "key" rock layers at many points over the area. The dominant structural feature of this part of the foreland is a general southward inclination or regional dip.

Local. The surface structure map of the Hilliards quadrangle, Figure 5, shows the elevations above sea level of the top of the Vanport limestone by means of 25-foot contours. In addition to direct elevations on the outcrop of this limestone, well records giving the depth to the limestone, and coal beds or other rock layers whose intervals to it were known were used in the preparation of this map.

As can be seen on this structure map, the Vanport limestone descends about 400 feet in a southerly direction in about 17.5 miles, or an average inclination of about 23 feet per mile. This regional dip is modified by a few north or northeasterly trending folds and by numerous minor irregularities and local undulations.

The most prominent fold in the quadrangle extends from one mile west of Branchton northeasterly to Kennerdell School. This fold is called the Homewood anticline in this report because it is considered to be a continuation of the Homewood anticline of the New Castle quadrangle. The axis of this anticline is not clearly defined across the entire quadrangle but appears to offset at irregular intervals. A dome of at least 25 feet closure is developed between Wick and New Hope Church. The steep dip in the southeast flank of the fold near Unity Church may reflect deep-seated faulting.

A general anticlinal fold extends from about one mile east of Hilldale northwesterly to North Washington, thence north to Eau Claire, and from Eau Claire it continues northeasterly to the quadrangle boundary. For convenience this fold will be called the Eau Claire anticline. Between it and the Homewood anticline is a broad gentle synclinal area.

The location of the oil and gas pools of the quadrangle is also indicated on the surface structure map, but the pools are not there differentiated according to producing sands because of the extensive overlapping of pools of different sands.

SURFACE STRATIGRAPHY

Approximately 1,060 feet of middle Pennsylvanian to lower Mississippian rock strata are exposed in the Hilliards quadrangle. A rather detailed study of these surface rocks was found necessary to the mapping of the structure and to a determination of the subsurface geologic conditions.

Pennsylvanian System

CONEMAUGH GROUP

The Conemaugh group extends from the top of the Upper Freeport coal to the base of the Pittsburgh coal. Throughout the northern half of the quadrangle the Conemaugh has been entirely removed by erosion and only the lower part of it is preserved in the southern part of the area. Where present it caps the higher hills and attains a maximum thickness of 240 feet in the hill half a mile southwest of Hilldale.

The Conemaugh consists predominantly of shale and thin-bedded sandstones. No detailed study of the group was made because it was unnecessary for the purpose of this report and because these strata are not well exposed in the quadrangle. The Mahoning red clay, a variable horizon of red and yellowish clay lying about 30 feet above the base of the group, was noted in several places in the southern part of the quadrangle and is useful as a general horizon marker.

ALLEGHENY GROUP

The Allegheny group as usually mapped extends from the top of the Upper Freeport coal to the base of the Brookville coal or its under clay. Exact delimitation of the group is difficult in this quadrangle because several coal members occur in its lower part and no final correlation of any one of them with the type Brookville coal has been made. In the adjoining Foxburg quadrangle Shaw and Munn[1] mapped as Brookville a coal which has been traced into the Hilliards quadrangle and found to lie about 360 feet below the top of the Upper Freeport coal. Later Renick[2] traced this and associated beds from the Beaver Valley to Brookville and concluded that this coal is in the Mercer formation of the underlying Pottsville group and that the true Brookville horizon lies about 60 feet higher in the section. Renick's correlation is here tentatively accepted, partly because it gives total thicknesses to the Allegheny and Pottsville groups and an interval from the Vanport limestone to the Pottsville which are more nearly in agreement with those found in the Zelienople quadrangle and other nearby areas.

The Allegheny group underlies a larger area than any other group in the quadrangle. It caps the plateau and hills in the northern part of the area and is exposed in the valleys and caps the lower hills in the southern part.

The Allegheny group is about 310 feet thick and is composed of shale and sandstone interbedded with coal, clay and limestone. Economically it is the most important outcropping group in the quadrangle. It is divisible into several members of which the following, named in descending order, are the principal ones in this quadrangle.

Principal members of Allegheny group in Hilliards Quadrangle

Name of member	Average interval to top of Vanport limestone Feet
Upper Freeport coal	250
Upper Freeport limestone	240
Butler (Upper Freeport) sandstone	—
Lower Freeport coal	220
Lower Freeport limestone	200
Upper Kittanning coal	110 to 130
Middle Kittanning coal	80 to 90
Lower Kittanning coal	40 to 50
Lower Kittanning clay	35
Vanport limestone	0
Scrubgrass (Upper Clarion) coal	15 to 30
Lower Clarion coal	30 to 45
Brookville coal	55 to 65

Although the total thickness of the Allegheny group remains fairly constant at about 300 feet, the individual members are very lenticular and somewhat irregular in position. The names of the members as

[1] Shaw, E. W. and Munn, M. J., Foxburg-Clarion Folio: U. S. Geol. Survey Geol. Atlas No. 178, 1911.

[2] Renick, B. Coleman, The correlation of Lower Allegheny-Pottsville section in western Pennsylvania: Journal of Geology, vol. XXXII, no. 1, Jan.-Feb. 1924, pp. 64-80.

used in this report imply only approximate position in the general section and not definite identity with the beds at the type localities.

The *Upper Freeport* coal is relatively unimportant in this quadrangle. It varies up to 4 feet in thickness, is being mined near the southeastern corner of the quadrangle and has been worked at West Sunbury. It is underlain by clay which is more persistent than the coal.

The *Lower Freeport* coal is very persistent throughout the southern part of the quadrangle. It lies 220 feet above the Vanport limestone and ranges up to 8 or 9 feet in thickness. Its maximum thickness is attained near North Washington where it has only a few feet of cover and is called the Summit vein. Typically it is separated by a binder into two benches. It is not extensively mined and is considered to have too high an ash content to be of much value.

A local coal lying about midway between the Lower Freeport and Upper Kittanning coals is mined half a mile east of West Sunbury. It lies 165 feet above the Vanport limestone, and was called Currie coal by Chance.[1]

Kittanning coal zone. In the brownish shales and lenticular gray sandstones extending from 25 up to 130 feet above the Vanport limestone lie the Lower, Middle and Upper Kittanning coals and their associated under clays. The Upper Kittanning coal is extensively mined in the southern and central parts of the quadrangle. Southwest of North Washington and east of Murrinville it is a cannel coal. The Middle and, less extensively, the Lower Kittanning coals are worked in the northern part of the area, especially near Nectarine.

The *Vanport* limestone member is the best key stratum in the quadrangle for correlating and determining the structure of the rocks. It crops out across the central and northern part of the area and is reported in numerous well records in the southern part. It is valuable for making lime and portland cement and is extensively quarried at Annandale, Wick, Branchton and elsewhere. It is a dark gray fossiliferous limestone. It is usually dense and massive but in places is thin-bedded. It ranges up to 20 feet, or possibly more, in thickness and averages about 10 feet but locally it disappears altogether.

Scrubgrass, Clarion and Brookville coals. The lower 40 to 60 feet of the Allegheny group consists chiefly of shale in which occur variable beds of coal, the Scrubgrass, or Upper Clarion, the Lower Clarion and the Brookville, and their under clays. The Scrubgrass and Brookville coals are thin and mined only for local use at a few places in the northern part of the quadrangle. Where present they lie about 15 to 30 and 55 to 65 feet respectively below the top of the Vanport limestone. The Lower Clarion is thicker and more persistent than the other coals of this zone. It has been mined in the valley of Slippery Rock Creek from Argentine to Keenan. It is characteristically underlain by several feet of clay.

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[1] Chance, H. Martyn, Northern Butler County: Second Penna. Geol. Survey, Report, vol. V, 1879, p. 65.

POTTSVILLE SERIES

The Pottsville series has long been considered to extend from the base of the Brookville coal, or its under clay, to the top of the Pocono series. It consists of massive sandstones separated by subordinate shale members and thin lenses of coal and clay. It crops out in the valleys and on the lower hills in the northern part of the quadrangle. It is here 170 to 200 feet thick and is divisible into the Homewood, Mercer, Upper Connoquenessing, Quakertown, and Lower Connoquenessing members.

The *Homewood* is the uppermost member of the Pottsville group. Typically it consists of gray, medium-grained sandstone 10 to 40 feet thick. This sandstone is designated 60 Foot Sand in most well records. Locally the entire member becomes shaly and in parts of the area it is represented entirely by shale.

The *Mercer* member consists of about 40 feet of brown to black shale in which occur irregular layers of coal, clay and siderite concretions. One of these coal beds lying about 120 feet below the Vanport limestone is 2 to 4 feet thick in parts of the area and has been mined on a small scale. This is the coal which was mapped as Brookville by Shaw and Munn.[1] It is overlain by 5 or more feet of dark slaty shale and underlain by clay. It serves as a key stratum for surface structure mapping over much of the northern part of the area where the Vanport limestone has been removed by erosion.

The *Upper Connoquenessing* is a coarse-grained massive gray sandstone averaging about 40 feet in thickness. Locally it is much erossbedded. It outcrops along the upper parts of the Scrubgrass and Allegheny valleys where, with the underlying sandstones, it forms precipitous cliffs. It forms the uppermost part of the Mountain sand of some well records and in others is recognized as a separate member and designated the 60 Foot or 40 Foot sand.

The *Quakertown* member lies between the Upper and Lower Connoquenessing sandstones. It consists of a few inches to 40 feet of dark brown to black shale in which occur siderite concretions and irregular sandstone, clay and coal lenses. The best exposure of the member seen is at Sutton Mill, where it is 36 feet thick. The coal of this member appears not to be of workable thickness anywhere in the quadrangle.

The *Lower Connoquenessing* is a massive sandstone closely similar in character and thickness to the Upper Connoquenessing. It is the uppermost part of the Mountain sand in most well records. It forms the bottom member of the Pottsville.

The Pottsville rests unconformably on the Mississippian. The rocks below the unconformity were tilted southward, probably folded slightly, and truncated by erosion before the Pottsville was deposited. Because of this unconformity the distance from the "key" Vanport limestone to Mississippian and Devonian sands increases about 40 feet southward across this quadrangle and has resulted in much of the misnaming of sands in the well records. This unconformity lies at an

[1] Shaw, E. W. and Munn, M. J., op. cit.

elevation of about 1,250 feet in the gorges of the Allegheny River and Scrubgrass Creek where its general position can be determined, although at no place in the quadrangle was a clean exposure of it found.

Mississippian System

Pocono series. The lower 330 feet (approximately) of exposed strata in this quadrangle belong to the Burgoon and Cuyahoga groups of the Pocono series. The upper Mississippian series, the Mauch Chunk, is not present in this quadrangle. It is thought that it was removed by erosion in the period of time represented by the unconformity at the base of the Pottsville.

BURGOON GROUP

The upper 250 to 270 feet of Mississippian rocks here consist of sandstone with subordinate shale members and constitute the Burgoon group. The correlation of individual members of this group with named stratigraphic units in other parts of Pennsylvania as suggested below is based on preliminary sections through the intermediate areas and should not be considered final.

Burgoon sandstone member. The upper 75 to 100 feet of this group consists predominantly of medium- to coarse-grained, gray to greenish sandstone. Typically this sandstone occurs in platy layers 4 inches to one foot thick interbedded with soft, gray or greenish shales. Weathering of the shale causes it to slump so rapidly that this part of the section is not cleanly exposed anywhere in the quadrangle. This general sand horizon constitutes the lower part of the Mountain sand of most well records.

Hempfield (Shenango) shale member. Below the Burgoon sandstone lies 75 to 100 feet of soft shale in which occur a few sandstone lenses. This shale is not sufficiently well exposed that its exact thickness or character can be determined. Apparently it is gray in its lower portion and greenish gray to red in the upper part. A few well records indicate that the upper 10 to 20 feet of it are red. Several wells in the southern part of the quadrangle record under the name Green sand a 10 to 15 foot sandstone layer in the central portion of this shale interval. This sand is not recorded in wells in the northern part of the area and was not identified with certainty on the outcrop.

The shale member described above occupies the stratigraphic position of the Shenango[1] shale, renamed Hempfield[2] shale by Caster, of Crawford County.

Shenango sandstone member. The lower 75 to 90 feet of the Burgoon group consists of sandstone and subordinate shale layers. The sandstone is coarse- to fine-grained, light to dark brown, and gen-

[1] White, I. C., Geology of Erie and Crawford Counties, Second Penna. Geol. Surv. Report Q4, p. 78, 1881.
[2] Caster, Kenneth E., Stratigraphy and paleontology of northwestern Pennsylvania: Bull. of Am. Paleo., vol. 21, no. 71, 1934, p. 141.

erally stratified in thin platy layers. Iron carbonate concretions up to 2 inches in diameter occur in both the shale and the sandstone and are especially abundant near the bottom of the member. The top 10 to 20 feet of the member consists of thicker bedded and slightly coarser sandstone. The shale layers range from less than an inch to 6 or more feet in thickness and from black or dark gray to brown.

The Shenango is designated Gray sand in well records. Its maximum thickness of about 90 feet is developed in the southern part of the quadrangle.

The interval from the base of the Shenango to the base of the Pottsville increases from about 40 feet at Tidioute to about 260 feet in the Hilliards quadrangle and 300 feet in the Foxburg quadrangle.

CUYAHOGA GROUP

Below the Shenango sandstone lie about 200 feet of shale in which a few sand members are reported, at irregular horizons, in well records. Eighty feet or less of the upper part of these shales lie above water level in the lower parts of the Allegheny and Scrubgrass valleys but are generally concealed. Half a mile north of the quadrangle, where Scrubgrass Creek enters the Allegheny River, 46 feet of dark gray fissile shale with interbedded thin layers of steel-gray, fine-grained sandstone are exposed. This probably represents the upper 46 feet of the Cuyahoga.

In the northwestern part of Pennsylvania there are many good exposures of the Cuyahoga. In Crawford County it is about 200 feet thick and has been divided into three members: the Meadville shale above, the Sharpsville sandstone, and the Orangeville shale below. The part of the Cuyahoga that outcrops in the Hilliards quadrangle probably belongs to the Meadville shale member and, perhaps, to the upper part of the Sharpsville sandstone. Subdivision of the group into distinct members was not found possible here, however, either on the outcrop or in well records.

SUBSURFACE STRATIGRAPHY—THE OIL AND GAS SANDS AND POOLS

List of Oil and Gas Sands

Approximately 2,700 feet of rock strata lying below the lowest exposed horizon have been penetrated while drilling for oil and gas. At least 45 different names have been applied by the drillers to the sands in this subsurface part of the section. To each sand, with a few exceptions, two or more different names have been applied in different parts of the quadrangle and some names have been applied to several different sands. This confusion of nomenclature is a natural result of the fact that few sands are continuous or regular in position over large areas, and that the distance of each sand from the Vanport limestone increases southward.

To clarify the nomenclature and to determine, as nearly as possible, the true stratigraphic conditions here, several detailed well-to-well correlation sections were drawn in various directions and positions

TABLE 1. SHALLOW OIL AND GAS SANDS OF HILLIARDS QUADRANGLE

Age of sands		Customary name of sand		Average interval to Vanport	Average thickness	Other names used in part of quadrangle indicated		Tentative correlations	Approximate proven productive acreage: Oil, Producing	Approximate proven productive acreage: Oil, Abandoned	Approximate proven productive acreage: Gas
PENNSYLVANIAN	Pottsville	Vanport			10				0	0	0
		Sixty Foot		70	30			Homewood	0	0	0
		Forty Foot		140	40	Sixty Foot, top of mountain		Upper Connoquenessing	0	0	0
MISSISSIPPIAN	Pocono	Mountain		220	140			Lower Connoquenessing and Burgoon	0	0	0
		Green		380	15				0	0	0
		Gray		415	80	Slippery Rock S. W. ¼		Shenango	0	0	0
		St. Patrick		700	15	Amber W. ½		Lower Corry	0	0	0
		Gas		740	20	Berea, Murrysville, Amber		Lower Knapp	0	0	1,400
DEVONIAN	Venango oil sand group	First formation	Clover Seed	870	10		Hundred foot S. E. ¼		0	0	600
			First	910	40	Hundred Foot S. ½		First of Oil Creek	230	610	690
			Salt	980	10	30 Foot S. E. 1/9		White of Tidioute	0	50	220
		Second formation	Rosenberry	1,025	15	30 Foot S. E. 1/9 Red Valley N. E. 1/9		Second of Tidioute	150	30	560
			Second	1,070	40	30 Foot S. W. ¼ Boulder S. E. ¼		Second of Oil Creek	13,960	960	1,580
		Third formation	Boulder	1,150	10	Third S. E. 1/9		Third Stray of Oil Creek	1,000	40	570
			Shira	1,170	10	Third S. E. 1/9			900	460	680
			Byram	1,190	10	Clover Seed S. E. 1/9		Third of Oil Creek	1,040	160	320
			Third	1,210	20	Fourth S. E. ¼ Glade S. C. 1/9			6,110	1,950	1,810
			Fourth	1,260	20	Fifth S. E. ½			0	150	80
		First Warren		1,680	40			Warren zone of Tidioute	0	0	Shows
		Second Warren		1,780	20						
		Clarendon		1,940	40			Queen	0	0	Shows
		Speechley Stray		2,040	20				0	0	Small
		Speechley		2,090	20				2,350	720	3,700

across the quadrangle. Wherever possible the correlations thus indicated were checked by a comparison of the character of the sand and of the oil occurring in it. Four of these correlation sections are published as Figures 1, 2, 3, and 4 in this report. Preliminary correlation sections have been run from this quadrangle to the Tidioute quadrangle and to the type areas of the Oil Creek Valley. The correlations thus drawn are shown in Table 1. In this table and in the discussion of the sands to follow, the name most commonly applied to each sand is used. Correlations with type localities are tentative, pending detailed work in the intervening areas.

Descriptions of the Sands and Pools

MISSISSIPPIAN SYSTEM

The Mississippian system is about 550 feet thick in this quadrangle and is considered to extend from the unconformity at the base of the Pottsville down to the top of a persistent red shale member that lies 790 to 810 feet below the top of the Vanport limestone. In the report on the Tidioute quadrangle[1] the Mississippian-Devonian was tentatively drawn at the base of the Knapp beds which there lie about 120 feet below the top of the Corry sandstone and 110 feet above the top of the First oil sand. This horizon has been traced southward into the Hilliards quadrangle and found to lie at the top of this red shale member. The upper 330 feet of the Mississippian is exposed and was discussed above. The lower 220 feet is known only from well records.

The upper 120 feet of this unexposed section consists predominantly of shale and constitutes the lower part of the Cuyahoga group described earlier in this report.

KNAPP GROUP

St. Patrick sand. The first unexposed sand that is consistently reported in the more complete well records lies about 180 feet below the Shenango or Gray sand and is designated the St. Patrick or Amber sand in most records and the Gas or Salt in others. It ranges up to 25 feet in thickness and averages about 15 feet. Although not commercially productive, small quantities of gas are reported in it in a few wells. The correlation sections northward from this quadrangle indicate that this sand is the equivalent of the Corry sandstone, or at least the lower member of that sandstone. It is thought to be the top member of the Knapp group of the Bradford district.

Gas sand. The sand designated Gas or Berea in most records here lies about 35 feet below the top of the St. Patrick sand and averages about 20 feet in thickness. Locally, especially in the southern part of the quadrangle, it is reported 50 to 100 feet thick. There maximum thicknesses apparently indicate failure to recognize or record the shale interval between the St. Patrick and this sand. The designation

[1] Cathcart, S. H., Sherrill, R. E., and Matteson, L. S., Geology of the Oil and Gas Fields of the Tidioute quadrangle, Pennsylvania: Penna. Topo. and Geol. Survey Bull. 118, 1938, p. 2.

"Berea" for this sand is more common in the northern part of the area. It is considered in this report to lie in the lower part of the Knapp group.

Typically the Gas sand is a fairly hard, fine-grained, light gray sandstone in which occur layers or lenses of loosely cemented "soft" sand. Several small gas fields producing from the softer portion of the sand have been discovered, especially in the western part of the quadrangle near Keisters and Barkeyville. In these producing areas the sand is generally less than 20 feet thick and productive from only 5 to 10 feet of the total sand thickness. The Barkeyville field is the largest so far discovered in this sand. It was discovered about 1905 and early wells in it are reported to have produced up to one million cubic feet of gas per day with a rock pressure up to 200 pounds per square inch. This field is now abandoned.

It is considered probable that undiscovered Gas sand pools are present in the western portion of the quadrangle. Apparently the location of Gas sand pools here is determined primarily by the local sand conditions, but this seems modified by structure and the structurally high areas should be favored in prospective drilling. The Barkeyville field is on a gentle southwest-plunging anticline and the Keisters producing areas lie on the crest or southeastern flank of the Homewood anticline (See Figures 5 and 6). In contrast to these favorable structural positions, the small Gas sand pool three miles northwest of Eau Claire is in a general synclinal area.

Devonian System

VENANGO OIL SAND GROUP

At the Oil Creek type locality the Venango Oil Sand group consists, in descending order, of the First, Second, Third Stray and Third Venango oil sands. This general unit is clearly recognizable throughout the Hilliards quadrangle, where it is about 410 feet thick and includes the sands from the top member of the First or Hundred Foot sand formation through the Fourth sand. The southward increase in total thickness of the group is primarily the result of the addition of a member, the Clover Seed sand, to the upper part of the First sand. The Fourth sand at the bottom of the group is probably an added member also.

The Venango Oil Sand group includes the most productive oil and gas sands of this quadrangle and has, therefore, received particular attention in this study. Ten general sand members are recognizable in the group. Each of these sands is lenticular and somewhat variable in stratigraphic position. Locally two or more members combine to form single sand units and in only a few places are all ten of the sands present as distinct members. The natural result of this stratigraphic complexity is that each sand has been variously named in different parts of the quadrangle. Some 21 names have been assigned in well records in the quadrangle to the sands of this group.

The ten sand members of the group may be considered as belonging to three general sand formations, the First, Second and Third forma-

tions. Within each of these formations the sand members "split," lens out or combine irregularly, but the shale intervals between formations seems fairly constant in that sand members of one formation do not, so far as known, combine within the quadrangle with members of another formation. In the discussion of individual sands below, each sand is considered as a member of one of these three formations of the group. The relative positions and lateral variations of these sands may be seen in the well-to-well sections accompanying this report.

FIRST SAND FORMATION

The upper three sand members of the Venango group in this quadrangle, together with the shales separating these sands, are parts of one general formation which is designated the First Sand formation in this report. This formation averages 120 feet in thickness. It is overlain by about 50 feet of red shale, the top of which is thought to be the Mississippian-Devonian contact here. In parts of the quadrangle, especially the southern and eastern parts, the three members combine into one thick sand. (See Fig. 1.) This thick sand is the Hundred Foot sand of most well records here and, probably, of the Pittsburgh and other quadrangles south of this. The term Hundred Foot is also used in well records in the Hilliards quadrangle, however, to designate the middle member of the formation, and, less commonly, the upper and lower members.

Clover Seed sand. The Clover Seed sand is the top member here of the First Sand formation, but is well developed as a separate sand only in the western part of the quadrangle. Through most of the central and eastern parts of the quadrangle it is united with the First sand below to constitute the upper part of the Hundred Foot sand of well records. (See Fig. 1.)

Where typically developed the Clover Seed is a pebbly sandstone, 10 to 15 feet thick, separated from the First sand by 20 to 30 feet of red or brown shale. It has produced gas in the western part of the quadrangle, especially at Wick, northeast of Unity Church, and in the Second sand oil pool south of Branchton. (See Fig. 6.) Only three wells now producing gas solely from this sand were found in the quadrangle and, so far as could be determined, it has produced no oil here.

First sand. The central 40 to 60 feet of the First Sand formation consists of fine- to coarse-grained gray sandstone. This is the most persistent sandstone member of the formation and constitutes, in general, the central part of the Hundred Foot sand in well records. With very few exceptions, it is called Hundred Foot sand in the pools producing oil or gas from it. As it is this central part of the formation that is thought to be correlative with the true First sand of Oil Creek, this member is designated First sand in this report.

The First sand is the most important oil- and gas-producing member of the First Sand formation. The three principal First sand oil pools in the quadrangle are aligned in a general northwesterly direction from Annisville to Ferris. (See Fig. 6.) Development of these three pools began in 1916, when wells producing up to 25 barrels of oil and

75 to 100 barrels of salt water a day, were drilled. The sand in these pools is 50 to 60 feet thick and overlain and underlain by dark gray shale. The oil production is derived largely from the upper part of the sand body where two "pay" sands, each 6 to 7 feet thick, occur. These "pay" sands are separated by about 6 feet of "tight," non-productive sandstone and underlain by an 8-foot stratum of coarse, pebbly, water-bearing sandstone. The bottom 10 feet of the sand is hard and non-productive. The oil is dark green in color and of 48° to 50° A.P.I. gravity. Small quantities of gas were produced with the oil, but apparently gas sufficient to saturate the oil and form a gas cap was not present. The wells in about half the area of these three pools are now abandoned (See Fig. 6) and the remainder pump about one-fifth of a barrel of oil per day. Sufficient drilling has been done between these pools to indicate definitely that the sand is there tight and non-productive, but very few wells have been drilled east of the Annisville pool and it seems quite probable that additional First sand oil accumulation may occur there.

Besides the above-mentioned pools, the First sand has produced small quantities of oil in 14 or more small pools and several isolated wells in this quadrangle. (See Fig. 6.) At least 9 small gas pools have been developed in this sand and numerous wells, especially in the southeastern part of the area, report "shows" or small production of oil or gas from it.

Except for the northwesterly alignment of the Argentine to Ferris pools, no systematic trend nor relation of the First sand production to structure is apparent. The sand is water-bearing over most of the quadrangle and in most pools producing from deeper sands, as in the Bullion-Clintonville area, casing through it is necessary.

Salt sand. The bottom member of the First Sand formation is recognizable as a separate member over most of the quadrangle. It is called Salt sand in most of the well records, especially in the northeastern part of the quadrangle, and Thirty Foot or Fifty Foot sand in others. This is the Thirty Foot sand of many of the well records in the southeastern part of the quadrangle, but the Rosenberry, and Second are also designated Thirty Foot in records there. In conformity with the usage in most well records, this bottom member of the First sand formation is called Salt sand in this report. It is definitely higher stratigraphically than the Salt sand of the Tidioute quadrangle and lower than the Salt sand of southwestern Pennsylvania. It occupies the stratigraphic position of the White sand of the Tidioute quadrangle, but definite correlation with that sand has not yet been made.

The Salt sand averages about 10 feet in thickness. Shows of oil or gas are reported from it in a few wells in the eastern part of the quadrangle, and small quantities of oil have been produced from it west of Six Points. Gas has been produced from it northwest of Lisbon. (See Fig. 6.)

SECOND SAND FORMATION

The Second Sand formation is a general stratigraphic unit extending from the base of the Salt sand to the base of the Second sand. This formation averages 130 feet in thickness and, where typically devel-

oped, consists, in descending order, of: a shale member 30 feet or more thick; the Rosenberry sand; red shale; and the Second sand.

Rosenberry sand. The Rosenberry is the upper sand member of the Second Sand formation. It is a light gray, coarse-grained to pebbly sandstone. It is 25 to 30 feet thick in the eastern part of the quadrangle, but thins to the west and is reported in very few wells in the western part of the quadrangle. Where typically developed it is separated from the Second sand below by about 30 feet of red shale. Along the central eastern edge of the quadrangle it reaches a thickness of 50 feet. This eastward thickening is in the bottom of the sand and continues to the Rosenberry pool of the Foxburg quadrangle, where it is combined with the Second sand.

The Rosenberry sand is designated Thirty Foot sand in most well records in the southeastern part of the quadrangle and Boulder or Second sand in a few. It is the Red Valley sand of the northeastern part of the quadrangle. It is thought to be correlative with the Second sand of the Tidioute quadrangle and with the Lyttle sand of Pleasantville.

The Rosenberry sand is producing oil at Hilliards, Rockland, and in several small pools in the southeastern part of the quadrangle. (See Fig. 7.) The oil is light amber in color and, at Hilliards, is of about 52° A.P.I. gravity. This sand has produced fairly large quantities of gas between Argentine and Higgins Corners. Development of this gas field began about 1924. It is now largely abandoned. Initially the wells produced up to two million cubic feet of gas a day with a rock pressure of 300 to 400 pounds per square inch. The gas here is described as very dry, indicating that this field is not continuous with the Rosenberry sand oil pools to the south. The gas accumulation here is apparently the result of the northwestern pinching out of the sand as it rises onto the Eau Claire anticline. (See Fig. 7.) This gas pool lies between two First sand oil pools (See Fig. 6) which otherwise might be thought to connect.

Second sand. In extent and character the Second sand is the most persistent and regular member of the Venango group in this quadrangle. It lies at an average position of 1,070 feet below the top of the Vanport limestone, but this interval increases from about 1,050 feet in the northeastern part of the quadrangle to 1,090 or 1,100 feet in the southern part. Typically it is a medium- to fine-grained light gray sandstone about 40 feet thick. A medial gray shale up to 10 feet in thickness is reported in it at a few places in the central and northeastern parts of the quadrangle. This medial shale is persistently present in the northwestern part of the quadrangle and divides the sand into upper and lower sand layers. The upper of these sand layers, 5 to 15 feet thick where present, does not extend west of a general northeasterly line from Coaltown to Bullion. The lower layer, 10 to 25 feet thick, continues to the western boundary of the quadrangle.

Throughout most of the central and northern parts of the quadrangle the Second sand is correctly designated Second sand in well records. In the southern one-third of the quadrangle it is designated

Thirty Foot sand in most records except in the southeastern part, where it is called Boulder sand. At Keisters, where only the lower sand layer is present, it is also designated Boulder.

The structure of the Second sand is represented by 10-foot contours on Figure 7, at the end of this report. This sand was chosen as the best horizon for depicting the subsurface structure because of its comparative persistence and regularity and because records to it are available over most of the quadrangle. In the western part of the quadrangle, where the upper layer of the sand is not present, 20 feet was added to the elevations on the top of the lower layer and the elevations thus obtained considered to be stratigraphically on the same horizon as the top of the sand where it is fully developed.

As can be seen by a comparison of Figures 5 and 7, the structure of the Second sand conforms in general with that of the Vanport limestone. The greater irregularity of the contours in some areas, as in the Bullion-Clintonville pool, is primarily the result of the close detail with which the structure is there controlled.

The Second sand is one of the most important oil- and gas-producing sands of the Hilliards quadrangle. It has produced oil over an area of about 14,920 acres, of which 960 acres are now classified as abandoned. It has proven productive primarily of gas over about 1,580 acres. For the location and structure of these proven productives areas, see Figure 7.

The largest and most important of the Second sand pools are the Bullion-Clintonville and the Cherry Valley. The Bullion-Clintonville pool is productive also from the Third sand and is discussed later in this report.

Cherry Valley pool: The Cherry Valley pool extends from midway between Eau Claire and Deegan to and beyond the eastern boundary of the quadrangle (See Fig. 7), where it overlaps the Third sand producing area of the Byram pool. As thus delimited, the Cherry Valley pool includes the areas locally referred to as Eau Claire, Cherry Valley, and Sandy Point Second sand pools. Although the productive possibilities of the Second sand in this area had been shown in 1879 by Third sand wells of the Byram pool,[1] active development of the pool began, about 1900, northwest of Eau Claire. The initial production of the wells, all of which were pumped, ranged from 1 to 50 barrels per day. Considerable gas was produced with the oil, especially in the northern part of the pool.

The Second sand of the Cherry Valley pool ranges from 25 to 45 feet and averages 36 feet in thickness. The lower one-half or more of the sand body is fine-grained and productive in only a few wells. The upper part of the sand is very coarse-grained to pebbly and constitutes the main "pay" sand. This "pay" sand ranges from 5 to 23 feet and averages 11 feet in thickness. Locally it is overlain by thin conglomerate lenses containing disc-shaped pebbles up to 1 inch or more in diameter. The structure of the top of the sand is shown on Figure 7. As there indicated, the largest productive area lies on the

[1] See, Chance, H. Martyn, Northern Butler County, Second Penna. Geological Survey Report V, 1879, p. 139.

Eau Claire anticline, and apparently this fold has influenced accumulation. Although the greater segregation of oil in the western part of the pool is apparently the result of this anticline, the pool as a whole is primarily the result of favorable sand conditions as indicated by its easterly extension beyond the limits of the fold. Up dip to the north the sand is relatively "tight" and contains gas in small quantities. To the south the sand is reported to be fine-grained and "tight."

The oil of this pool is dark green in color and ranges from 36° to 38° A.P.I. gravity. The Second sand oil becomes progressively lighter both in color and in gravity from the Clintonville-Bullion pool to and across the Cherry Valley pool. Cherry Valley pool wells were spaced about 350 feet apart and very little redrilling between locations has been done. Reliable estimates of the reserves of this pool cannot be made because no core analyses are available, but the average "pay" thickness is 11 feet, and 2,640 acres, of which 150 acres are abandoned, have been proven productive. The present average daily production of the wells is probably between ¼ and ½ of a barrel of oil and three to four times that quantity of water.

So far as could be determined, no secondary recovery methods have been applied to the Cherry Valley pool. It is considered doubtful that repressuring or water flooding would prove successful here because of the conglomerate lenses and other "loose" streaks in the upper part of the sand.

Several additional small productive areas of oil from the Second sand are shown on Figure 7. The nine small pools trending northerly from the western end of the Cherry Valley pool obtained the oil in the upper part of the sand. In all these pools the production was small. Apparently the upper layer of the Second sand contains oil, usually in non-commercial quantities, from the central part of the Dullion-Clintonville pool eastward to a general line from Cyrus to Pisgah School. Between this line and Cherry Valley pool it contains principally gas in small quantities. This gas has been produced south of Rockland, north of Lisbon and elsewhere as indicated on Figure 7. In the drilling of the Third sand wells in the Byram pool south of Crawford Corners the Second sand furnished enough gas to fire the boilers and in some cases was used directly in the engine cylinders as the motive power.

THIRD SAND FORMATION

The lower 170 feet (approximately) of the Venango Oil Sand group of this quadrangle consists of lenticular, fine-grained to conglomeratic, gray or brown sand members interstratified with dark shale. This general stratigraphic unit is referred to in this report as the Third Sand formation. Oil- and gas-productive sand members are recognizable at five general horizons in this formation, but no one of them is continuous or entirely constant in stratigraphic position over the quadrangle. At the top of the formation is a persistent shale member 20 or more feet in thickness. For convenience, and also to indicate their tentative correlation with Oil Creek types, the sand members will be discussed under the general headings Third Stray, Third and Fourth sands.

Third Stray sands. In the interval extending from 20 to 70 feet below the Second sand occur two general sand members, the "Boulder" and the Shira. In the northwestern part of the quadrangle these sands are present only as thin "shells." In the eastern part of the area they are more persistent and locally combine into one thick sand mass, but comparatively few wells record both sands. These two sands are parts of a general sandy zone which occupies the stratigraphic position of the Third Stray of Oil Creek.

"Boulder" sand. The sand designated "Boulder" in this report lies 30 to 40 feet below the base of the Second sand and averages about 10 feet in thickness. The name "Boulder" is used for this sand because that is the name by which it is known in the central-eastern and northeastern parts of the quadrangle. Correlation of it with the Boulder sand of any other area is not intended. As nearly as can be determined from the data at hand, this "Boulder" sand lies stratigraphically about midway between the Second and Third Stray sands of Oil Creek, which places it in the approximate position of the "Little Minister" Stray of the Tidioute quadrangle. In the central and northeastern parts of the quadrangle the "Boulder" ranges from 5 to 30 feet thick. In the southeastern part of the area it is 5 to 20 feet thick and designated Stray or Third sand in well records. This is the Third sand of the western part of the Petrolia field which was considered by Carll[1] to be correlative with the Oil Creek Third Stray. In the western part of the quadrangle the "Boulder" is present only as "shells," but the name Boulder is locally applied in records to the lower layer of the Second sand.

The "Boulder" produces oil and gas, usually in small quantities, in several pools throughout the eastern part of the quadrangle. (See Fig. 7.) The principal producing area is east of Walley Mill. This is a western extension of the Petrolia field and covers about 830 acres in the Hilliards quadrangle. The sand in this area ranges up to 20 feet in thickness. The "pay" sand averages about 10 feet in thickness and lies in the lower part of the sand member. Initially the daily well production ranged up to 80 or more barrels, but today it is less than a barrel. The oil is green in color, of about 45° A.P.I. gravity and congeals rapidly at low temperatures.

Shira sand. The Shira sand is a medium-grained to pebbly, greenish-gray sandstone ranging up to 14 feet in thickness. It is well developed only in the east-central part of the quadrangle. Stratigraphically it lies about 10 feet below the bottom of the "Boulder" sand and about 60 feet below the Second sand. It is the approximate correlative of the Third Stray of Oil Creek and the Third of Tidioute.

Shira Streak pool. The Shira has produced relatively large quantities of oil in the "Shira Streak"—a long, narrow, northeast-trending pool—and in several pools bordering this Streak on the northwest. (See Fig. 7.) Oil production from the Shira Streak started about 1893 on the Alexander Bell farm near Pisor School. Initially many of the wells flowed up to 100 barrels a day and one well is reported

[1] Carll, John F., Second Penna. Geol. Survey, Report 15, 1890, p. 82.

to have flowed at this rate for a year, after which it declined gradually. The productive sand of the Streak is 3 to 12 feet thick and is underlain and overlain by dark shale. In the northeastern part of the pool the top 1 foot or less of the sand contains pebbles up to 1 inch or more in diameter and is gas bearing. The oil "pay" sand is medium-grained and averages 8 to 10 feet in thickness. Typically the sand reaches its maximum thickness in the central portion of the Streak. It thins rather abruptly to a "shell" 1 foot or less thick at the south edge of the Streak, but is more continuous to the north, where several outlying oil and gas pools have been developed. Although many of the early wells are abandoned, others still produce in quantities ranging up to 1 barrel per day. Considerable redrilling of the pool and of outlying areas is being done. Repressuring has been successfully practised on a small scale, and would probably prove successful over most of the pool. The oil is green in color, of about 46° A.P.I. gravity and does not congeal in cold weather. Very little water is produced with the oil. The sand has not been cored.

In the outlying areas north of the Shira Streak where the Shira was productive primarily of gas the wells averaged about 500,000 cubic feet per day. In the gas-producing portion of the Streak, as at Annisville, the wells initially produced 3 to 4 million cubic feet of wet gas per day. The original rock pressure was about 350 pounds per square inch.

Third sands. In the 35-foot interval extending from 80 to 115 feet below the Second sand, or 1,190 to 1,225 feet below the position of the Vanport limestone, occur extensive lenses of pebbly sand. Sand occurring in the upper part of this 35-foot section is called Third, Byram or Byram Third sand in records here, and sand in the lower part is commonly designated Third or Fourth sand.

Byram Third sand. The Byram Third, or Byram sand, averages about 10 feet in thickness and lies 80 to 90 feet below the Second sand. Except very locally, this sand is not present northwest of a general line extending from Rockland to Sherwin. Southeast of this line it is recognizable in most of the more complete well records.

Byram pool. The Byram pool, named for Byram Center (now Sandy Point), is located about midway between Six Points and Crawford Corners, and was referred to by Chance[1] as the Six Points-Crawford Corners pool. It was discovered in 1878 and actively developed during the succeeding ten years. The Byram sand here ranges up to 15 feet and averages about 10 feet in thickness. In general, it thickens to the east. It is a soft, fine-grained, brownish-gray sand in which pebble streaks occur locally. Apparently the entire sand thickness is "pay" sand.

When first discovered, many of the wells produced daily by natural flow up to 35 barrels of oil and large quantities of gas. No definite recent production data are available, but the wells probably produce about ½ to ¼ of a barrel daily. Some of the leases are being operated

[1] Chance, H. Martyn, op. cit., p. 138.

on a vacuum, which is the only secondary recovery method practised. The oil is amber-green in color and of about 43° A.P.I. gravity.

Venango Third sand. The Venango Third sand of this area, which is considered correlative with the Third sand of Oil Creek, lies about 10 feet below the bottom of the Byram sand, and about 100 feet below the Second sand. It is a medium-grained to pebbly sandstone averaging 20 to 25 feet in thickness and from gray to light chocolate-brown in color. This is the Third sand of the Bullion-Clintonville pool, the Murrinville Third, the lower, productive part of the Glade Third of the Hoover pool and the so-called Fourth sand of that part of the Butler County Cross-Belt which lies in this quadrangle. The areas producing from this sand are indicated in Figure 8. The structure of the sand is not depicted on this map because the top and bottom of the sand are apparently gradational into the adjoining shales and, except locally, cannot be accurately located from the records. As nearly as can be determined, the structure of this sand conforms in general with that of the Second sand.

Production. In the part of the Butler County Cross-Belt included in the southeastern part of this quadrangle the sand averages about 35 feet and ranges up to 50 feet in thickness. The upper 10 feet (approximately) of this body contains small pebbles and is designated "Clover Seed" in records. The "pay" sand is reported to lie in a "white" sand below this "Clover Seed." This entire sand body is designated "Fourth" sand in records. Considerable gas occurred with the oil, especially in the northern part of the pool, and several wells in the Speechley gas area north of this encountered gas in this "Fourth" sand.

Hoover pool. The Hoover pool, named for the Hoover farm on which the development started, is in the south-central part of the quadrangle (See Fig. 8) and is locally referred to both as the Hoover and the Glade pool. The first producing well, the Lackey, was a small pumping well in the northern part of the pool and completed in 1892. Flowing wells with initial daily productions up to 60 or more barrels were common in the early history of the area. These wells ceased flowing because of "paraffining" up, and as this occurred new wells were drilled. Twice the pool has been almost or completely abandoned, but a general program of redrilling began about 1922 and is still in progress. Recently drilled wells produce initially 4 to 5 barrels per day and are pumped until decline, partly because of paraffin deposition, necessitates their abandonment. The wells are closely spaced, partly because of the "tightness" of the sand and partly because the paraffin deposition often causes abandonment before normal exhaustion of the oil. In parts of the pool the average spacing is less than 1 acre per well if all the wells that have been drilled are counted.

The Third sand in this pool ranges up to about 30 feet in thickness. The "pay" sand is medium- to fine-grained, generally lies in the upper part of the sand body, ranges up to 20 feet and probably averages about 12 feet in thickness. The core analyses of two wells on the Campbell farm in the east-central part of the field show 13.5 and 20.25

feet of sand averaging respectively 11.5 and 9.6 percent porosity. The total oil content of the sand at these two wells was calculated to be 4,030 barrels per acre and 5,625 barrels per acre. If an average of 4,000 barrels per acre is assumed for the entire field of about 2,000 acres, a total reserve of 8,000,000 barrels is indicated. As the pool is notably "spotty," however, this estimate of total reserve may be considerably in error. The permeability as indicated by the two core analyses ranges up to 56 millidarcies, but is less than 4 millidarcies for most of the sand.

A large part of the Hoover pool lies in a flat and locally marshy valley called the glade. This is a part of the glacial lake bottom referred to earlier in the report. The lake fill here ranges up to 80 feet or more in thickness. Many of the early wells were poorly plugged and some of the operators report that fresh water is entering the sand and gradually moving southward. The oil is green in color and of about 40° A.P.I. gravity. Small quantities of water are produced with the oil. The customary practice calls for casing through the First or Hundred Foot sand.

Adjoining the Hoover pool on the northeast lies a rather extensive Third sand gas pool. Most of the wells of this pool produce less than 500,000 cubic feet daily.

Bullion-Clintonville oil pool. The Bullion-Clintonville is the major oil pool of this quadrangle. It is productive from the Second and Third sands and is overlapped on the southwest by the Gas sand production of the Barkeyville pool. (See Fig. 5.)

Although wells capable of producing small quantities of oil had been drilled in and near this pool prior to 1876, the Phillips well on the Gealey farm about two miles northeast of Bullion is credited with having started the development of the Third sand production of the pool. This well, completed August 2, 1876, gauged 125 barrels per day flowing by heads. It was followed by a rapid development of the Third sand part of the pool. This Third sand area is outlined on Figure 8 and will be discussed later.

Although the wells drilled to the Third sand indicated the possibilities of the Second sand in the Bullion-Clintonville pool, active development of Second sand production was not begun until 1897. This development started on Bullion Run about one mile north of Bullion and extended southward over the area indicated on Figure 7. The major development occurred from 1900 to 1910. The initial production of the wells was small, generally 5 to 25 barrels per day. Shooting of the sand was regular practise and none of the Second sand wells flowed naturally. Small quantities of gas—apparently little, if any, more than necessary to saturate the oil in the reservoir—were present and this gas is now almost completely exhausted. The present production of the Second sand wells here averages about one-eighth of a barrel of oil and an equal quantity of water per day. The wells were spaced about 300 feet apart and very little redrilling between locations has been done. Customary casing practise calls for about 400 feet of 6¼ inch into or through the Gray sand and about 900 feet of 4¼ inch through the First sand.

Although the Second sand in this pool ranges up to 50 feet in thickness, only the lower 10 feet of this is generally "pay" sand. Typically this "pay" sand is a uniform, white, fine- to very fine-grained sandstone. Locally pebble lenses occur at the top of the sand. Over most of the pool a medial gray shale break divides the sand body into upper and lower layers. The upper layer does not extend west of a line from Bullion to Walters School, and is much less productive than the lower layer over the remainder of the pool. Locally, as between Kimes and Walters Schools and southeast of Brush Hill School, the two layers are combined.

Structurally, the Second sand oil accumulation of this pool is located on the southwest plunging Homewood anticline (See Fig. 7), and is apparently due, in part at least, to this fold. South and southwest of the pool the sand is saturated with salt water. West and east of the pool the sand is generally "tight." "Shows" of oil and a few small producing areas are present east of the main pool. (See Fig. 7.)

Core analyses of the sand were obtained for four different parts of the pool. From these analyses and from the character and general production history of the sand in other parts it is estimated that the "pay" sand has an average porosity of about 20 percent and now contains about 450 barrels of oil and 750 barrels of water per acre-foot. With a proven productive area of 11,500 acres (of which 520 acres are classified as abandoned) and an average "pay" thickness of 10 feet, a total reserve of about 51,000,000 barrels is indicated for the Second sand part of this pool in the Hilliards quadrangle. One-third to one-fourth of this oil could probably be recovered by water flooding, but this does not seem economically feasible at present. Only one of the cores gave permeability data, but the average permeability of the sand is probably less than 10 millidarcies.

An experimental modified five-spot water-flooding project was undertaken in 1929 one mile north of Nectarine. Although successful in increasing the output from 1/6 to 3 barrels of oil per day, the operations were discontinued in 1929, partly because of the general business depression. Repressuring with air has been attempted in several parts of the pool with varying results. On the whole, the air repressuring has not proven very successful here and gas sufficient for use in repressuring is not readily available.

The Second sand oil of this pool is black to very dark green in color and of 33.8° to 34.4° A.P.I. gravity. In general, the oil becomes progressively lighter in gravity eastward across the pool.

The Third sand producing area of the Bullion-Clintonville pool (See Fig. 8) was rapidly developed after the Phillips well of 1876. Several of the early wells flowed up to 3,500 barrels daily.

The Third sand here is light gray in color and ranges from a uniform medium-grained sand 10 to 20 feet thick to a conglomeratic sand 20 to 30 feet thick. The thicker, coarser sand, in which were located the large flowing wells, occurs principally in the western, especially northwestern part of the pool. The pebbles of this coarse sand range up to ¼ inch in diameter and consist predominantly of white quartz.

In the southern three miles (approximately) of the pool, the sand is fairly fine-grained, only 10 to 15 feet thick, and the wells produced initially up to about 25 barrels per day.

The oil is dark green in color and ranges from 38° to 42° A.P.I. gravity. Very little water is produced with the oil and in parts of the field the sand is reported to contain no water. Sufficient gas is still produced in most of the pool to run the engines pumping the oil. Repressuring has been practised for about five years on one lease in the northwestern part of the pool. Definite data on the results of this repressuring were not obtained, but from the variable character of this sand it is thought that repressuring is the proper secondary recovery method to apply. Two leases in the northeastern and one in the southern part of the pool are operating on a vacuum. In one of these the production is reported to have been temporarily increased from about 4 to about 50 barrels per month. Water flooding has not been attempted and the general opinion is that it would not be successful here. Several wells are reported to have been cored here, but the core analysis for only one, the Summit No. 62, was obtained for this report. This well is in an area of small production in the northwestern part of the pool and the analysis is probably not typical of the pool. This core analysis indicated 11.5 feet of sand with an average porosity of 11 per cent, an average oil content of 180 barrels per acre-foot and a permeability ranging up to 3.1 and averaging 1.42 millidarcies.

Although the Third sand is anticlinal in structure in this pool (See Fig. 8) the oil accumulation here is thought to be primarily the result of sand conditions. Thinning and "tightening" of the sand limit the pool in all directions except, possibly, the north. The northern terminus of the pool lies outside this quadrangle and has not been studied in detail. In the two small abandoned pools south of the main pool the Third sand is only 6 feet thick.

Fourth sand: A sand, the top of which lies about 35 feet below the bottom of the Third sand and about 1,280 feet below the Vanport limestone, is reported in most of the deeper wells. In a few well records this sand is designated the Fourth sand. As no other sand lies between this sand and the Third, Fourth is the proper designation for it and is used in this report. This is the Fifth sand of most records, especially in the southeastern part of the quadrangle where the true Third sand is incorrectly called the Fourth.

The Fourth sand averages about 20 feet in thickness. It thins to the northwest and is reported as only a "shell" in the northwestern half of the quadrangle. A small oil pool probably in this sand was discovered in 1873 in the Rumbaugh farm south of Whiskerville. (See Fig. 8.) The wells produced up to 7 barrels of 42° A.P.I. gravity oil per day.[1] A well near Claytonia is producing small quantities of gas from this sand, and gas production from it was formerly obtained in at least one well south of North Washington. In the Speechley gas field southeast of North Washington several wells re-

[1] Chance, H. Martyn, op. cit., p. 112.

eord gas in a sand ranging up to 70 feet in thickness and occupying the stratigraphic position of the combined Byram, Third and Fourth sands.

Sands below the Venango Oil Sand group

WARREN AND CLARENDON SANDS

Although several hundred wells in this quadrangle, especially in the southeastern part, have penetrated 900 or more feet below the Venango group, little information on the deeper sands, except the Speechley, was recorded. In most of the records listing the deeper strata the first persistent sand below the Venango group is called the First Warren. This sand lies about 1,680 feet below the Vanport limestone and averages about 30 feet in thickness. It occupies the general stratigraphic position of the First Warren of the Tidioute quadrangle, and a few wells record red rock above it as in that quadrangle, but definite correlation of these deeper sands has not been made. A little gas is reported in this sand in a few wells but no commercial production has been obtained. In a few wells a sand lying about 100 feet below this First Warren sand is recorded as Second Warren.

Sands in a general zone extending from about 1,900 to 1,970 feet below the Vanport limestone are recorded as Clarendon sand. Gas is reported in this sand in several wells, especially in a belt trending northeasterly through the central part of the quadrangle. Most of these wells are included in the list of selected records published in this report. This Clarendon sand occupies more nearly the stratigraphic position of the Queen sand of the Tidioute quadrangle than of the true Clarendon sand.

SPEECHLEY SANDS

Extending from about 2,030 to 2,140 feet below the Vanport limestone is a general sand formation in which two members, the Speechley Stray and the Speechley, are recognized in well records. The Speechley Stray has an average thickness of 20 feet and lies about 2,040 feet below the limestone. It is reported productive of gas in some wells in the Speechley gas field, but is relatively unimportant.

The top of the Speechley sand lies 2,070 to 2,110 feet below the Vanport limestone and about 20 feet below the Speechley Stray. It is described as a uniform, fine-grained, hard, chocolate-colored sandstone where productive. It ranges up to 40 feet and averages about 25 feet in thickness. It is an important source of gas in the eastern, especially southeastern, part of the quadrangle, and of oil in the Hooker pool.

Hooker oil pool: For convenience the Speechley oil pool in this quadrangle is designated in this report the Hooker pool. This pool was discovered in 1901 and actively developed from 1901 to 1905. It is approximately 9 miles long and 1½ miles wide. It covers about 4,420 acres in this quadrangle and extends southwesterly about two miles beyond the quadrangle boundary.

The structure of the Speechley sand in the Hooker pool and in the gas pool adjoining it on the north are shown on Figure 8. The structure is a general south dip modified by local undulations in the sand.

The accumulation of the oil is the result of southward thinning of the sand, not of folding. An isopachus map of the sand shows that the south and southeastern limit of developed production correlates closely with the 10-foot sand thickness contour. The sand contains very little water and apparently the oil was trapped in its down-dip migration by decrease in the thickness and permeability of a large northeast trending sand lens. Gas accumulated up the dip of the lens.

The initial daily production of the wells ranged up to about 75 barrels. Accurate initial daily production data were obtained for 114 wells drilled during 1901 to 1904. The wells averaged 24.03 barrels and ranged from ½ to 72 barrels. The thickness of the sand in these wells averaged 19.28 feet and ranged from 10 to 40 feet. Where the sand is over 10 feet thick there was no correlation between initial production and either sand thickness, date of completion (if within the first three years) or structural position of the wells. It is concluded, therefore, that porosity and permeability were the principal factors determining well productiveness. The usual spacing was 6 to 10 acres per well and very little redrilling between locations has been done.

The present daily production is less than ¼ barrel per well. Water flooding and repressuring have been attempted without success and the pool is being steadily abandoned.

North, especially northeast, of the Hooker pool lies an extensive Speechley gas-producing area. The limits of the main part of this field are indicated on Figure 8, but several isolated wells north of these limits indicate that this sand contains gas in small quantities over most of the eastern part of the quadrangle. Most of the wells of the main gas field were drilled during 1904 to 1915. The initial daily production of the wells ranged up to about two million cubic feet with a rock pressure of 600 to 700 pounds per square inch. The sand ranges between 20 and 40 feet thick. The "pay" sand averages about 14 feet and ranges up to 25 feet thick.

SANDS BELOW THE SPEECHLEY

Several wells in the quadrange have penetrated below the Speechley sand but for only six were records obtained which listed the deeper sands. These six are included in the list of selected records. Wells 72 and 98 of this list record a sand 30 or more feet thick lying about 3,200 feet below the Vanport limestone, or approximately 1,100 feet below the Speechley sand. This is stratigraphically the lowest sand in the records obtained. Between it and the Speechley sands, six or more horizons are listed but the records do not agree on the stratigraphic positions of these sands. Apparently a general sand horizon is present in the interval extending from about 2,430 to 2,530 feet below the Vanport limestone, and another 2,700 to 2,800 feet below. The terms Tiona, Bradford and Kane are used in the records for the deeper sands but no uniformity in the usage of these names is followed except that the sands so designated lie below the Speechley of this quadrangle.

The Oriskany sandstone, untested in this quadrangle, probably lies at a depth below the Vanport limestone ranging from about 4,600 feet at the northwestern corner of the quadrangle to about 5,600 feet at the southeastern corner. The anticlinal areas shown on Figure 5 and described earlier in this report are thought to be the most favorable places for testing this sand. A well located one mile northeast of the northeast corner of this quadrangle found no sand at the Oriskany horizon, but several wells within a few miles of the southwest corner of the quadrangle found 15 or more feet of sand. In general, then, the southwestern part of the quadrangle seems the more favorable part for testing the Oriskany, and the dome north of New Hope Church (See Figure 5) is thought to be particularly worthy of attention. The depth to the Oriskany at this dome would probably be about 4,950 feet below the Vanport limestone, which is at or very near the surface there.

SELECTED WELL RECORDS

Of the 3,000 well records collected, 243 are published below. These records were carefully selected as the most complete and representative of the sands. Through the Venango group the sands have been carefully correlated and are listed under the names used in the report. Final correlation within the quadrangle of the deeper sands has not been completed and the names assigned in the well records to these sands are indicated in the list by key letters. The locations of the wells whose records are here published are shown on the First sand production map, Figure 6. This map also shows by conventional symbols the location and drilling results of isolated wells for which no records were obtained.

Serial No.	Date	Name of ore	Owner	[illegible]	[illegible]	Manganese ores	Iron ores	Bi Antimony ores	Zinc ores	Lead ores	Silver ores	Gold ores	Bismuth ores	Mercury ores	Antimony ores	Bitumen ores	Third ores	Fourth ores	Symmetry ores	Red ores	Other metals	Other metals	Notes details
				Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	Top Bottom	
1	[illegible]	Mica [illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			1862				1862
2	[illegible]	M Y [illegible]	[illegible]											[illegible]									[illegible]
3		[illegible]	[illegible]	[illegible]	[illegible]						[illegible]			[illegible]							[illegible]		
4		[illegible]	[illegible]											[illegible]									
5	[illegible]	[illegible]	[illegible]								[illegible]												
6		[illegible]	[illegible]											[illegible]									
7	[illegible]	[illegible]	[illegible]																				[illegible]
8		[illegible]	[illegible]																				[illegible]
9		[illegible]	[illegible]																				
10	[illegible]	F P [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]																		[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]																				
14	[illegible]	[illegible]	[illegible]																				
15	[illegible]	[illegible]	[illegible]																				
16	[illegible]	[illegible]	[illegible]																				
17	[illegible]	[illegible]	[illegible]																				
18	[illegible]	[illegible]	[illegible]																				
19	[illegible]	[illegible]	[illegible]																				
20	[illegible]	[illegible]	[illegible]																				
21	[illegible]	[illegible]	[illegible]																				
22	[illegible]	[illegible]	[illegible]																				
23	[illegible]	[illegible]	[illegible]																				
24	[illegible]	[illegible]	[illegible]																				
25	[illegible]	[illegible]	[illegible]																				
26	[illegible]	[illegible]	[illegible]																				
27	[illegible]	[illegible]	[illegible]																				
28	[illegible]	[illegible]	[illegible]																				
29	[illegible]	[illegible]	[illegible]																				
30	[illegible]	[illegible]	[illegible]																				
31	[illegible]	[illegible]	[illegible]																				
32	[illegible]	[illegible]	[illegible]																				
33	[illegible]	[illegible]	[illegible]																				
34	[illegible]	[illegible]	[illegible]																				
35	[illegible]	[illegible]	[illegible]																				
36	[illegible]	[illegible]	[illegible]																				

Township	Formation	Name of well	Owner	Limestone cap Top	Limestone cap Bottom	25-foot sand Top	25-foot sand Bottom	Muddy sand Top	Muddy sand Bottom	Bird sand Top	Bird sand Bottom	Bradford sand Top	Bradford sand Bottom	Bradford sand Top	Bradford sand Bottom	Chert Rock Top	Chert Rock Bottom	Final sand Top	Final sand Bottom	Bell sand Top	Bell sand Bottom	Bowlesburg sand Top	Bowlesburg sand Bottom	Second sand Top	Second sand Bottom	Hooker sand Top	Hooker sand Bottom	Blake sand Top	Blake sand Bottom	Bryan sand Top	Bryan sand Bottom	Third sand Top	Third sand Bottom	Fourth sand Top	Fourth sand Bottom	Speechley sand Top	Speechley sand Bottom	Bell sand Top	Bell sand Bottom	Other sands Top	Other sands Bottom	Total Depth
16	1366	J. A. McKie No. 16	Clyde Iron																					873p	868																	874
17	1349	Hollister No. 8	Lincoln Oil Co.																					968p 968 969p	979 967 964																	
18	1425	McKeldin No. 18	Barry Oil Co.															926	966a					1106 1108 c 1111p	1112 1111																	1140
19	1348	Moler No. 8	H. J. Hoffman Est.																					1134p	1137																	1150
20	1324	Rock Oil No. 19	Freeland Oil Co.							819	819							760 Water	779 108					870 890c 905p	887 903 946	956	1005					1000	1070					825p				1095
21	1387	Peterson No. 17	Ramsey Est.								815								866					1000p	1020																	1040
22	1388	Cunningham No. 77	Ramsey Est.								820								913					1024p	1038																	1054
23	1397	Davis No. 17	Thorn & Irwin															854	953					907p 910p	925 953																	973
24	1340	Gleed No. 12	S. T. Ramage																					1056p	1060																	1100
25	1340	C. Russell No. 4	A. L. Sandapple et al																					1056	1068							1125p	1145									
26	1345	Hollister No. 13	Ramsey Est.					900											953					812p	864							1074p	1095									1110
27	1340	Clay No. 8	S. S. Ramage																960					879p	1012							1124p	1132									1140
28	1400	Hollister No. 20	S. T. Ramage															909	956					1014	1054																	1115
29	1377	Hollister No. 66	S. T. Ramage															799	841					1072p	1096																	1105
30	1391	Henderson No. 37	S. T. Ramage, Jr.																977					1064p 1070p	1088 1090																	1071
31	1436	Henderson No. 61	S. T. Ramage, Jr.															839	920					1070p	1083							1124	1136									1146
32	1415	Davis No. 1	J. C. Atwell																979					1041p	1060																	1080
33	1407	Bullet No. 2	Inwood																					1061p	1085																	1100
34	1407	McKee No. 46	Mrs. Burns															1013						1177p	1189																	1210
35	1407	Foster No. 67	Foster Est.					837										850	917					970p	1048																	
36	1406	Bortinger No. 2	Bortinger Est.															826	897					1043p	1073							1149p	1205									1215
37	1362	Whiddon No. 13	Mrs. Carrie Whiddon															723	809					956	996							1049p	1062									1115
38	1471	Schmitt No. 62	S. T. Ramage																					1029p	1061							1139p	1151									1164
39 A	1373	Kennedy	John Eakin																																							1200
39	1368	Copperhead No. 13	John Eakin															714	773					875	907							1079p	1095									1096
40	1366	Strane No. 1	Hodgson															741	807					849	905							1064p	1085									1095
41	1370	Frank Eakin No. 1	Ion Riddle et al.					4										727	773p					848 851d	874 906							1090d	1106									
42	1387	Deal & Fertig Carll 1 p. 13		79	100			182	231									112 [illegible] [illegible]	162 [illegible] [illegible]	136	176			949	1051	1060	1115					1140	1141	1Pay	1214			1Pay [illegible] 1160	1205 [illegible] 1189	810	143		1340
43	1375	Kennedy No. 11	John Eakin																													1077p	1088									1112
44	1367	Finney No. 12	S. L. Cobain															920	970					849	886							839p	854									911
44 A	1116		Phipps																																					1109 a		1400
45	1361	Kennedy No. 16	John Eakin															661	691					831	846							773p	789									851
46	1359	Sc. 1 Phipps No. 18																						873 869p	895 895																	

Map Number	Number	Name	Lime stone Top	Lime stone Bottom	Bird sand Top	Bird sand Bottom	Moscow sand Top	Moscow sand Bottom	Hiley sand Top	Hiley sand Bottom	Pulaski sand Top	Pulaski sand Bottom	Hiles sand Top	Hiles sand Bottom	Floyd sand Top	Floyd sand Bottom	Bull sand Top	Bull sand Bottom	Horsecreek sand Top	Horsecreek sand Bottom	Second sand Top	Second sand Bottom	Boulder sand Top	Boulder sand Bottom	Hilda sand Top	Hilda sand Bottom	Big Lake sand Top	Big Lake sand Bottom	Wind sand Top	Wind sand Bottom	Sunset sand Top	Sunset sand Bottom	Spearing sand Top	Spearing sand Bottom	Red sand Top	Red sand Bottom	Other sands Top	Other sands Bottom	Total depth
67	1180	Menjes No. 11	Salmon Bluffs																																				
68	1111	Stevens No. 1	Salmon Bluffs																																				
69	1153	Hudson No. 13	President Hill Co.																																				
70	1111	Bickle No. 1	Lee Bickle	13	80				131		8000																												
71	1128	McFadden No. 3	N. F. Davis et al.		13				115																														
72	1111	Ellegri Bluff	Mac. L. & H. No. 102				44	810	860	910					591	640	655	1000																					
73	1161	C. M. Williams Hie No. 11	Lee Bickle																																				
74	1100	Moore No. 6																																					
75	1110	Cliff Hole No. 1																																					
76	1200	Shook No. 1	A. Hewlins																																				
77	1160	H. M. Pulaski No. 3		13	11				990																														
78	1150	Hood No. 1	P. J. Eelin																																				
79	1130	Eelin & Moist No. 1	P. J. Eelin				121	170																															
80	1101	Edson Eelin No. 3							273																														
81	1171	C. Dalton No. 1	R. W. Meale																																				
82	1121	F. J. Gillis No. 2	R. W. Meale																																				
83	972	South Pass No. 1	W. J. Cox																																				
84	1200	Edson Eelin																																					
85	1365	D. F. Scull	Mac. L. & H. No. 1010		6	140	150		250	270	400	450																											
86	1311	J. P. Clay	Mac. L. & H.				111	215	270	312	380	420	470	500	630	671	711	861																					
87	1121	H. M. Stone	Mac. L. & H. No. 1123														150	200																					
87	1215	W. J. Wallis	Mac. L. & H. No. 1011		11	90		130	141	170	240	300	615	660	707	1																							
88	1285	Boyd	Mac. L. & H.		11	80	110		411	504	556	670	700	714	111																								
89	1321	A. Barlanan	Mac. L. & H. No. 25		15	0	130		351	390	460	564	640	708	726																								
90	1350	Annie Hale	Mac. L. & H. No. 35		110	110	151		403	470	540						505	571	950	1050					1190	1111													

Plate number	Excavation number	Name of tomb	Tomb type	Limestone (top)	Limestone (bottom)	Limestone (top)	Limestone (bottom)	Limestone (top)	Limestone (bottom)	Mudstone (top)	Mudstone (bottom)	Gneiss (top)	Gneiss (bottom)	Diorite (top)	Diorite (bottom)	Granite (top)	Granite (bottom)	Sandstone (top)	Sandstone (bottom)	Basalt (top)	Basalt (bottom)	Dolerite (top)	Dolerite (bottom)	Hematite (top)	Hematite (bottom)	Calcite (top)	Calcite (bottom)	Alabaster (top)	Alabaster (bottom)	Faience (top)	Faience (bottom)	Glass (top)	Glass (bottom)	Wood (top)	Wood (bottom)	Pottery (top)	Pottery (bottom)	Copper (top)	Copper (bottom)	Bronze (top)	Bronze (bottom)	Total tombs
91	1011	Bakarel	Chamb. Ill., Sect. V	80	80			1.0			66			118	114			64	63																					764	764	63
																																										400
92	1016	M. Thomas	Mast. I. & II. Dyn. 11					7.0	120	300	400	1.0	0.7	777	804	906	966	569	573	1011	1096																				
93	1019	Sem Hesepi I Khamdi	Mast. I. & II. Dyn. 11			11	41	300	1.0	175	300	300	400					118	122																						
														796	798			604	600																						
94	1110	D. G. Lindig																																								
95	1120	Fekure Lindig	Mast. I. & II. Dyn. 11a					47	100	190	200	200	400	600	617		1	300	300	300 w 300 d	300 w 300 d																				
																				300 w 300 d	300 w 300 d																				
96	1122	F. S. Gadsby	Mast. I. & II. Dyn. 11a			30	56	195	272	300	300	180	132	0			0	300	300	300 w 300 d	300 w 300 d																				
																				300 w 300 d	300 w 300 d																				
97	1127	Gabody		11	43			100	100	400	471	140	161	654	714			403	400	146	403															1128	1140						
																																										1144
																																										1146
																																										1148
																																										1150
																																										1152
98	1130	Sedenen	A. P. Hourie					100	100			132	200	200	200	200	200			200 w 200 d	200 w 200 d																				
																				200 w 200 d	200 w 200 d																				
																				200 w 200 d	200 w 200 d																				
99	1132	A. M. Gordon	Mast. I. & II. Dyn. 11a			36	60			300	300	315	312	532	600	600	600	796	800	400 w 400 d	400 w 400 d			361	300																
																				400 w 400 d	400 w 400 d																				
100	1133	Cornish				18	52	140	140			476		600	628			700	700	200 w 200 d	200 w 200 d																				
																		700	700	200 w 200 d	200 w 200 d																				
101	1136	J. M. Simpson	Mast. I. & II. Dyn. 11a	18	36					220		400	500		772	800				400 w 400 d	400 w 400 d																				
102	1204	J. D. Bishop												600	600	700	700	134	1020																						
103	1206	Lurtor Dy. II	Double Cist Tom																	300 w 300 d	300 w 300 d																				
104	1208	Imaing Dy. 11	Limestone Vessel Tom			11													304	300																					
105	1209	Hunter Dy. 6	Hunter's Lodge																	1110																					
106	1211	Ahmed Dy. 11	Ahmed Cist Tom	80																1110 w 1110 d	1100 w 1110 d																				
107	1213	Imepet Dy. 11	Limestone Stelomay																1050																						
																			400	400																					
108	1214	Pepsenb Dy. 1																	1400	1400																1100 w 1100 d	1150					
																			1300	1300																1300 w 1300 d	1300					
109	1216	Dinam Pashiu	Final Mastaba								270								1110	400																1100	1100			400	50	
																			1100	400																					
110	1217	John Dickinson	Mast. I. & II. Dyn. 11a				41	80		170	300	200	111	221	300				900	900																1100	1100					
111	1218	D. Goodwin Dy. 1	Pepsy Wall																1500																	1500	1500					
112	1227	Wm. Dickinson	Mast. I. & II. Dyn. 11a	100	111					140	400			400	400				1000	1100										1311	1300			1400	1300					1300 w 1300 d	1300 d	
113	1228	Dreden Dy. 6	Lid							300	300	300				700	7	670		1000 w 1000 d	1000 w 1000 d			1000	1	1000	1110	1100	1100	1100	1100	1100	1100			1300	1300			400		1300
																				1000 w 1000 d	1000 w 1000 d																				
														600	6				1000								1100	1100		1300												1300
114	1230	W. Wassell																												1300												
115	1232	H. T. Murfin																		100 w 100 d	1000 w 1000 d																				1000
116	1234	Mirfanin Dy. 6																900	900	900	900			1110																	1170
117																																				1100					1300

Map Number	Drawing	Name of well	Owner	Elevation		20-foot sand		40-foot sand		Mountain sand		Gilly sand		84 Fairfield sand		Iles sand		Clover Leaf sand		First sand		Fall sand		Rosemary sand		Second sand		Boulder sand		Blue sand		Pitman sand		Third sand		Fourth sand		Symphony sand		Red rock		Upper Maxon		Lower Maxon		Total depth
				Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	
111	1147	Church No. 1								2000 364	1027							2010																														
110	1151	McCullough No. 7		140	150					115		600								3090	3092					1100	1120																				1200
120	1158	Pete Kelley	Miss. S. & H. Co. No. 10	56	68	130	155	140	150	230	300	1.1	150	112	213	354	741			3000 3000 3000 w						1100p 1000 1000	1120 1150	1170	1175			1300	1320	1300	1350							1400 4230	4.0 40		1700
115	1163	McAnulty Estate No. 3	Wells Oil Co.																							1300 1300p	1310 1320																			
122	1164	Slagle	Mehas et al	127																							1200																			
122	1177	Amos Sexton	Miss. S. & H. Co. No. 8	120	132	210	225	250	270	250	310	140	150	100	111					1050 1050	1050		1104	1114			1300p 1300 1270	1307			1410	1470	1300	1400	1405	1470					4.0	40			
113	1221	Irwin Farm																		900	w						1000p	1123																	800	7	
128	1228	Calvin Sloan No. 7	Louisa Oil Co																								1170 1200 1270	1225																	1000 4.00	1000	
128	1261	H. Sloan No. 7	Louisa Oil Co																								1050 1000 1200																			
127	1271	H. O. Hunter No. 9	H. H. Hunter																	870 900	w						1070 1070	1111																		
128	1311	Port Sloan No. 4	Wells Oil Co																								1070 1062 1062	1071 1060 1060																		
129	1309	Wm. Laples No. 1	Neally, Caler et al	43	57															990	1000						1140 1140p	1176 1182					1220	1300											
130	1319	Ever Est. No. 1	Neally, Caler et al.	39																990							1120 1120p	1164								1070	1070									
131	1396	Millard No. 4	Tice et al																								1110 1110p	1140 1140					1200	1200											
132	1365	McLandress	Mas. I. & H. Co. No. 1111	108	111			155	111	115	470									1005	1100	1145	1170w			1500	1285	1400	1125	1300	1400											400 400	140 300		
132	1250	G. H. Anderson No. 11	President Oil Co.																							1145		1150	1120			1140	1190												1500
114	1190	Collins No. 1	President Oil Co																							1140p	1400	1170p	1170			1170p 1200 1140p	1400												
135	1306	J. W. McCord No. 1	President Oil Co	110				250		270 130		140														1090 1090p	1091 1090	1067	1092			1067	1080									400				
136	1321	Robinson No. 10	J. Gisbers																	941	967					1000p	1111	1145	1195			1221													
137	1329	Eagleville No. 1	Eagleville			125	154	135	150	135 119	160 170	140	150	100		102	1210			1005 1100	1102 w					1070 1070p 1000 2000p	1091 1000 1020	1140	1160			1190 1400	1400					1700 1400	1000	1.0 1000	1000				
138	1375	McCracken No. 1	President Oil Co	15																												1500p	1540												
139	1395	Morgan No. 7		170																1055	1100					1300	1370					1400p	1420									400	4		
140	1371	McKee No. 1	McKee Bros																													1400 1400p													
141	1420	J. C. Gibson No. 1	Mas. I. & H. Co. No. 1					141			170									1007 1111	1107 w		1110	1170		1150	1190	1100	1190	1100 1000p	1400 1400														
142	1397	C. Tarwater	Mas. I. & H. Co. No. 1[illegible]			50	90	140			300	110	130	150	200			840 860	840 w	1000 1000 1000 1000	1010 1000 w	1070				1000	1107			1170	1190	1200	1210	1270 1270	1311					4.0 4	400	40			
143	1.0	Samuel Pell	Mas. I. & H. Co. No. 7			200	220	250	400	111	500	545	590	900	p										1170	1170				1300											4.00 1.0	1.0 1.0	40	
144	1111	Infinita Oil & Co. 13	Inf. Petroleum Co																	1000	1100	1100	1100	1300	w																	400	400		

| Reg. No. | Date of Arr. | | |

Map Number	Section	Name of well	Owner	Limestone Top	Limestone Bottom	Official sand Top	Official sand Bottom	Mound sand Top	Mound sand Bottom	Litter sand Top	Litter sand Bottom	St. Patrick sand Top	St. Patrick sand Bottom	Clay Sand Top	Clay Sand Bottom	Flower Bend sand Top	Flower Bend sand Bottom	First sand Top	First sand Bottom	Salt sand Top	Salt sand Bottom	Rosedale sand Top	Rosedale sand Bottom	Second sand Top	Second sand Bottom	Bedford sand Top	Bedford sand Bottom	Riley sand Top	Riley sand Bottom	Pilgrim Lime Top	Pilgrim Lime Bottom	Third sand Top	Third sand Bottom	Fourth sand Top	Fourth sand Bottom	Spearbley sand Top	Spearbley sand Bottom	Red rock Top	Red rock Bottom	Other sands Top	Other sands Bottom	Total depth
170	1816	S. H. Crosby	Mfg. L. & H. Co. No. 828	56	59			158	183	190	190	210	232			860	865	890 / 1000						1000 / 1010	1110											1170 / 1180	1180 / 1185				
171	1799	James Moore	Man. L. & H. Co							391	398	410	411	430 / 441	441 / dry	780	797	820 / 830	831 / 841					940 / 945	945 / 948											1170 / 1180	1185 / 1190				1220
172	1879	G. A. Hamilton	Man. L. & H. Co. No. 3672															971	1000					1155	1170			1190	1197									1700 / 1705	1710 / 1720				1750
173	1880	Helen Tinker	Man. L. & H. Co. No. 2133															840 / 850	852 / 864			1000	1030			1110	1120	1113	1127									1800 / 1805	1822 / 1830	1845 / 1850	1857 / 1860		1910
174	1911	Crossman	Mfg. No. 1509					318	402	402	425			111	301			450	465			1000	1004	1030	1041							1200	1254					1115	1145				1200
177	1943	Wm. Campbell		11				248	300	320	340							519	529					1002	1013	1170	1180													1700 / 1840	1760 / 1860		1866
178	1964	E. W. Tinkle	Mfg. No. 1509	106	121	145	159	202	175	253	270	753	845	880	900	963	977	943	1000					1140 / 1146	1177	1291 / 1294	1297	1291 / 1292	1298													1300	1871
179	1318	Hoff			135													900 / 1000	1047 / 1050	1052	1056											1092 / 1092	1096 / 1097									1197	1212		1225
180	1726	McCaslin																947	1002					1206	1145	1204	1220	1196	1206			1174 / 1179	1202 / 1207										1400
181	1812	N. Glen No. 1	C. Hillards															953	1000					1120	1133			1220	1231			1240 / 1242	1246 / 1271										1445
182	1918	D. W. Holt	Hindman	100																						1202 / 1212	1275					1302 / 1312											1390
183	1301	J. McKinney	H. L. & H. Co. No. 1806					190	200			1031	1043					1145 / 1150	1153 / 1170					1205	1220			1140 / 1141	1161 / 1170											2011 / 2040	2017 / 2042		2051
184	1127	A. H. Thompson	M. L. & H. Co. No. 1930																																	1740	1750			6941 / 7046	7001 / 7070		7095
185	1913	A. McKinney No. 1	A. McKinney	140	200							849						1112	1132					1152	1152					1123		1140 / 1142								3002 / 3077		
186	1352	M. W. Campbell No. 2		213	192			140	152			372				1129		1180						1262	1262							1075 / 1095						1560	1580				1700
187	1224	L. Hines No. 4		161	145			140	165			454	510					1050 / 1110			1276			1240	1279	1310	1328					1340 / 1362											
188	1321	Harvey Bell	Will McCartler	191	202													1135 / 1140						1230	1241							1400 / 1407											
189	1211	Geo. Meale No. 10	Lyle Hillards															1078 / 1090										1322 / 1330				1390 / 1400											1470
190	1225	A. L. Bell No. 3												797	840			1050 / 1070						1146	1150							1234 / 1240											1250
191	1145	T. C. Dunn No. 7	Troy Burns	98	112													964 / 1000			1145	1160		1162	1213	1230	1264					1290 / 1300											1356
192	1312	P. S. Campbell												790	800																	1320 / 1340											1340
193	1119	Hall No. 3	D. L. Hindman	33	10			204	238			678 / 696	726 / 730					820	836					1041	1111			1160 / 1170	1190														1190 / 1191
194	1111	Lanis No. 1	H. A. King	195																								1171 / 1175	1183														
195	1131	Ribs No. 3	J. M. Chaisty	170																								1300 / 1310	1305 / 1307														1140
196	1509			131	136			190	199									941	950			1140	1195									1435 / 1440	1452										1454
197	1126	McJunkin No. 4																1000 / 1006	1184							1200 / 1205	1214	1264															1302
198	1142	McJunkin No. 2		190	210													1000 / 1010	1150							1221 / 1230	1240																1300

Index Number	Year Drilling	Name of well	Owner	Limestone Top	Limestone Bottom	Second sand Top	Second sand Bottom	Third sand Top	Third sand Bottom	Mountain sand Top	Mountain sand Bottom	Gray sand Top	Gray sand Bottom	Fifth sand Top	Fifth sand Bottom	Sixth sand Top	Sixth sand Bottom	Upper Knox sand Top	Upper Knox sand Bottom	Fifth sand Top	Fifth sand Bottom	Sixth sand Top	Sixth sand Bottom	Seventh sand Top	Seventh sand Bottom	Eighth sand Top	Eighth sand Bottom	Ninth sand Top	Ninth sand Bottom	Tenth sand Top	Tenth sand Bottom	Eleventh sand Top	Eleventh sand Bottom	Twelfth sand Top	Twelfth sand Bottom	Thirteenth sand Top	Thirteenth sand Bottom	Fourteenth sand Top	Fourteenth sand Bottom	Fifteenth sand Top	Fifteenth sand Bottom	Other sands Top	Other sands Bottom	Other sands Top	Other sands Bottom	Total depth
250	1879	Campbell No. 19	Dobbins	110	200																																										400
251	1911	F. W. Boyd No. 1	T. W. Phillips & Co.															403	405																									1005 1007 1009 1011				2130
252	1908	M. F. Dorthenpark No. 1	T. W. Phillips & Co.	255	258											976	980																									1111 1116 1118				1164
253	1921	Essex No. 1		170																																						1109 1113 1124 1128				1168
254	1896	Ward No. 8	Troutman & Co.	200												403																										1005				1207
255	1914	Tom Smith No.																400	406	875	886																					1050	1125			1210
256	1921	Alpheus Trading	P. F. B. Co. No. 1				275	131	139 141	408 420	419	460	458	847	867	911	1001 1004	1054	1056	1113	1131	1237	1239	1259	1270	1308 1315	1306 1314	1360 1365	1366 1370																	1270	1275			1300
257	1911	H. S. Stephenson	P. F. B. Co. No. 1																																							1111 1115 1114				1200
258	1911	Henry Stephenson No. 1		111														1001	1020					1046	1051	1309	1366															1111	1118	1274	1290	1366
259	1911	A. F. Boyce No. 1	T. W. Phillips & Co.	115	275	276	278	301	311	415	441	456	479					1002	1004	1046	1064			1099	1103	1303	1375															1130	1132	1275 1280				1375
260	1908	Ralph Martling No. 1		250																1294	1295					1291	1314															1154	1164	1314	1320	1320

Key to symbols used in list of sources and layers:

a Coal.
b Brown sand.
c Logged as Bird sand.
d Logged as Parks sand.
e Logged as First Walton sand.
f Logged as Second Walton sand.
g Logged as Thirsties sand.
h Logged as Spearing Bling sand.
i Logged as Tiona sand.
j Logged as Sherrick sand.
k Logged as First Stradford sand.
l Logged as Second Stradford sand.
m Logged as Third Stradford sand.
n Logged as Kane sand.
o Logged as Fifth sand.
p Producing oil sand.
q Formerly productive oil sand.
r Show of oil.
s Producing gas sand.
t Formerly productive gas sand.
u Show of gas.
v Fresh in sand.
w Salt water.
x No sand.
y Shot.
z Sand "broken."
* Only whole below Third sand.

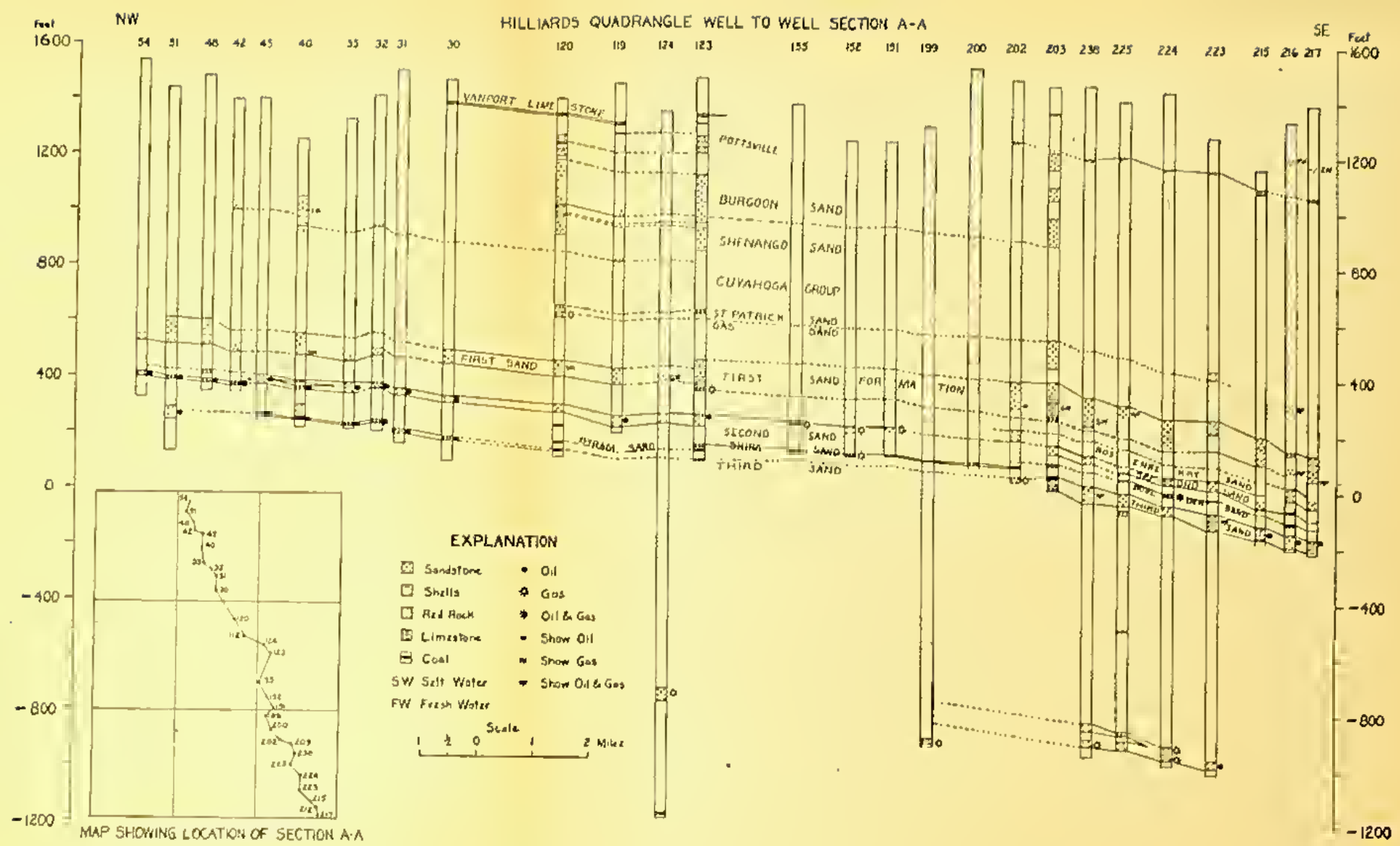

Figure 1. North-south correlation section across quadrangle

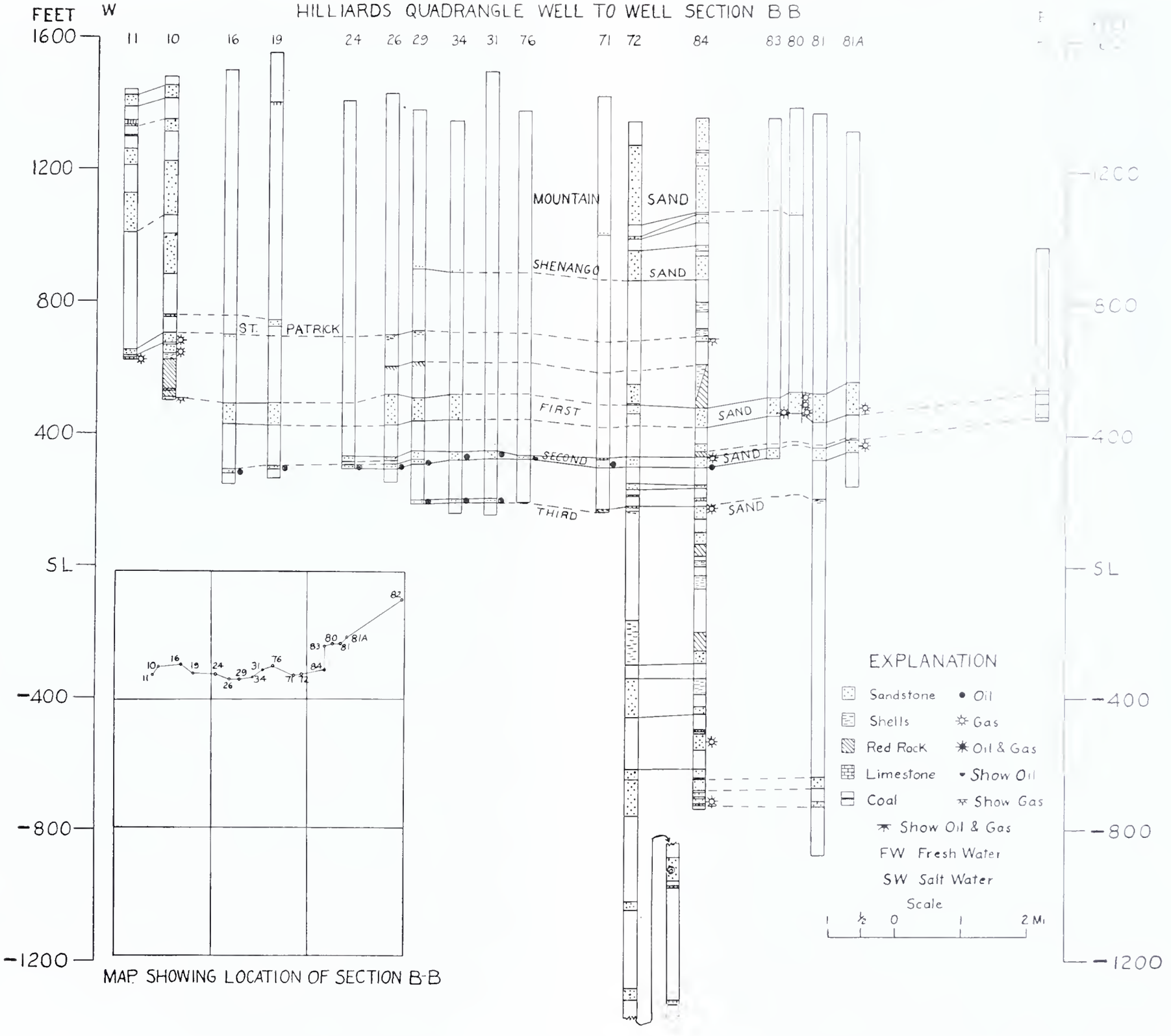

Figure 2. East-west correlation section across northern part of quadrangle

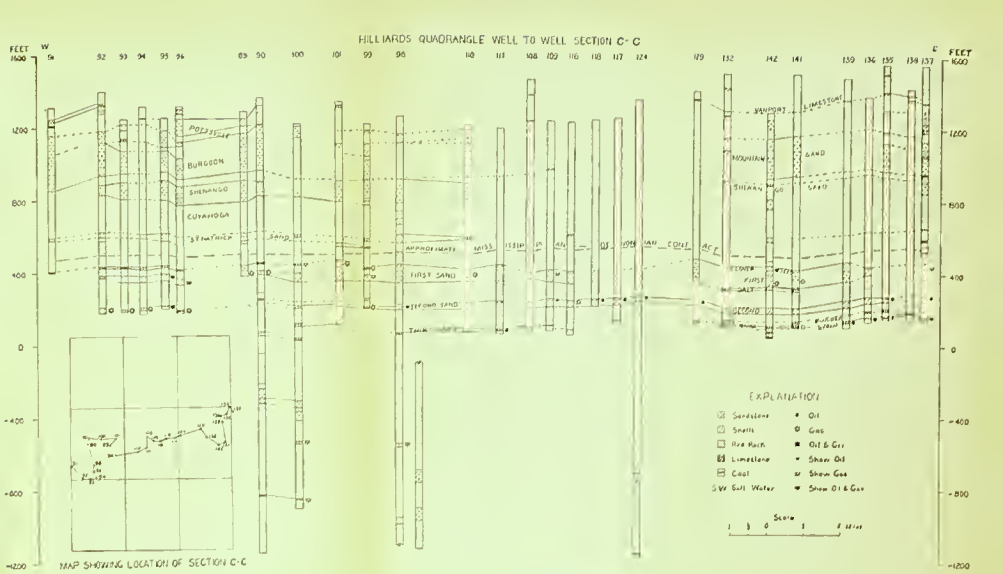

Figure 3. East-west correlation section across central part of quadrangle

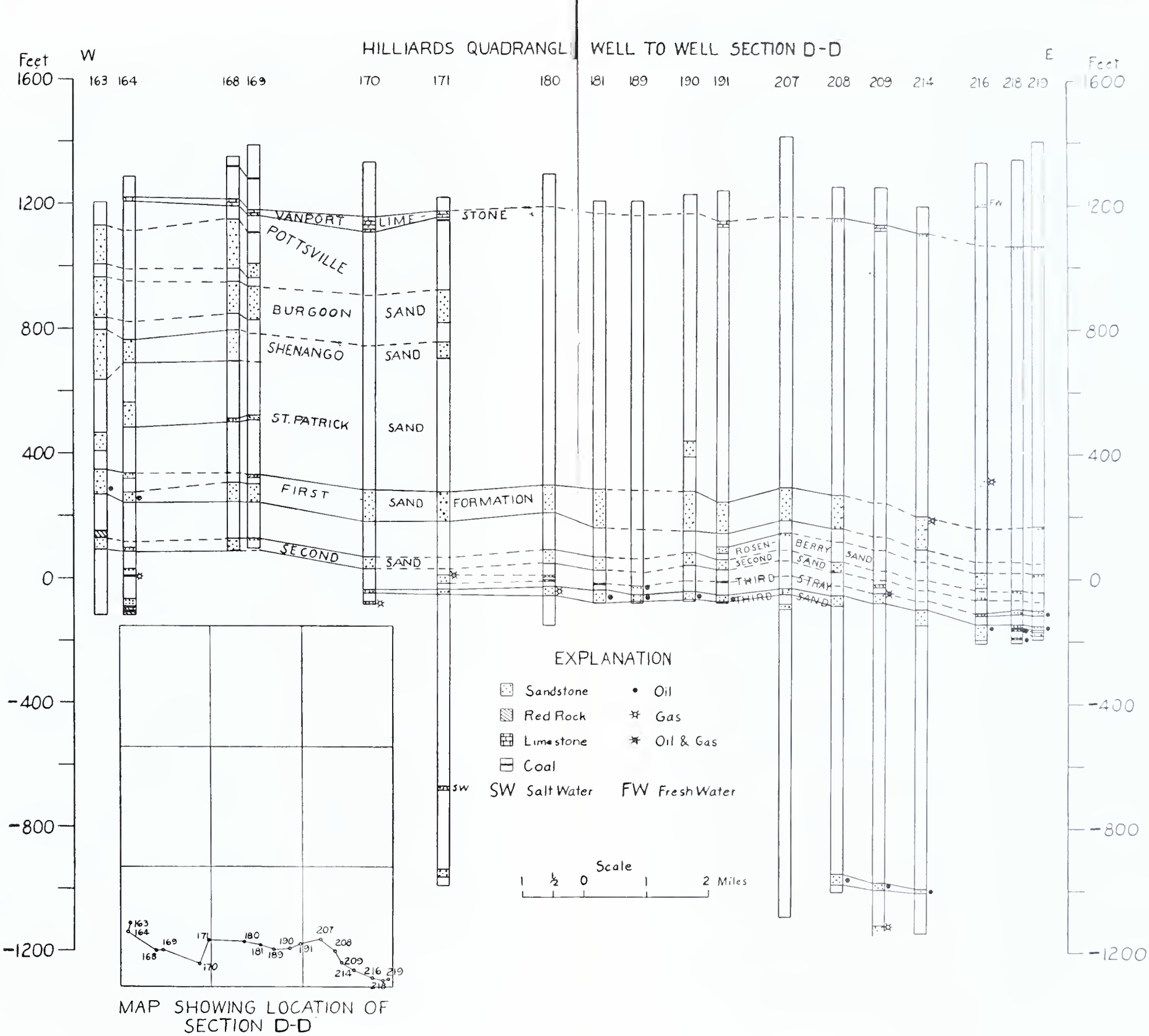

Figure 4. East-west correlation section across southern part of quadrangle

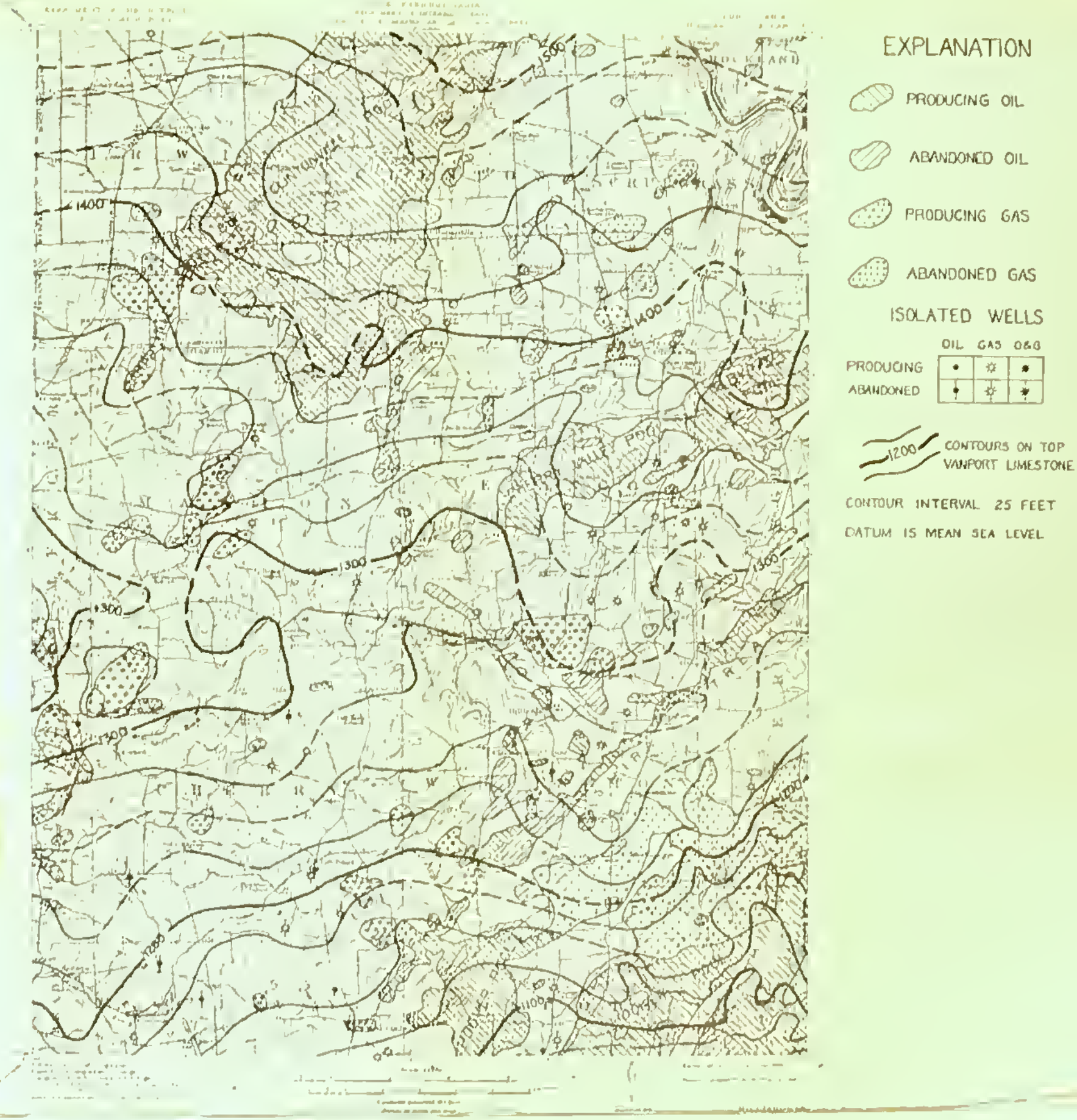

Figure 5. Map of Hilliards Quadrangle showing producing areas and surface structure.

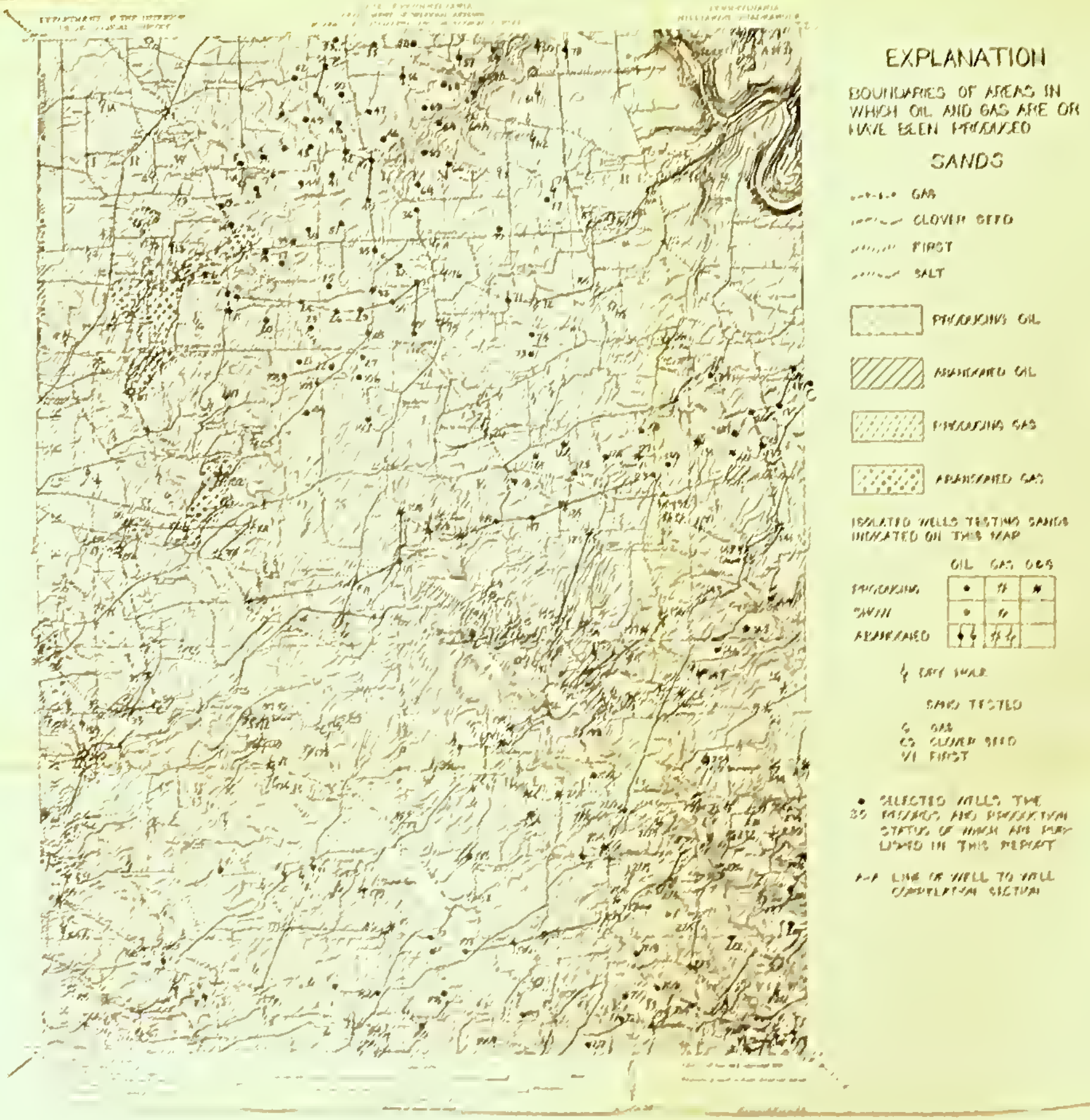

Figure 6. Map of Hilliards Quadrangle showing producing areas of Gas, Clover Seed, First and Salt sands, the location of wells the records of which are published in this report, and the lines of the correlation sections.

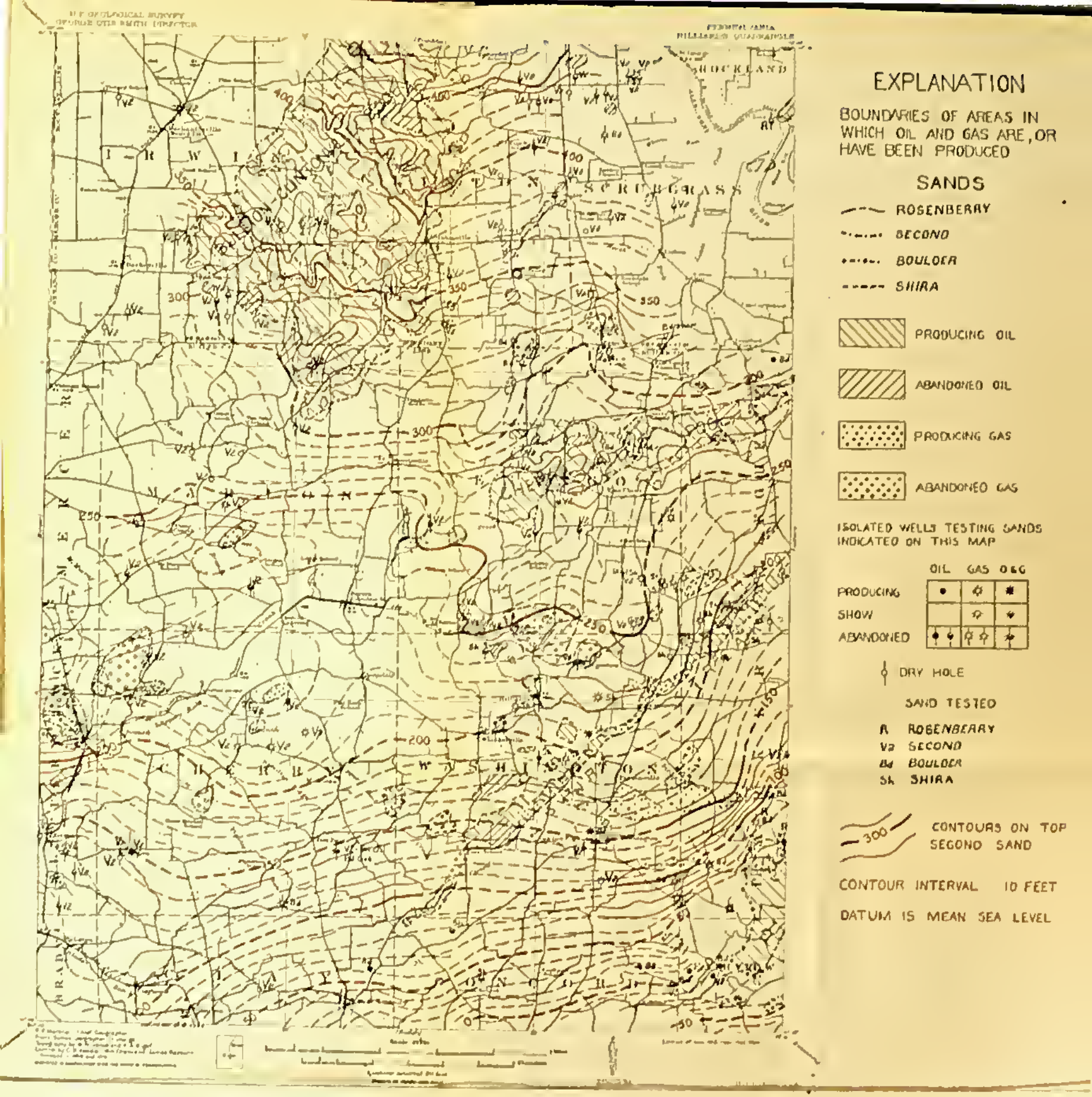

Figure 7. Map of Hilliards Quadrangle showing producing areas of Rosenberry, Second, Boulder and Shira sands and structure of Second sand.

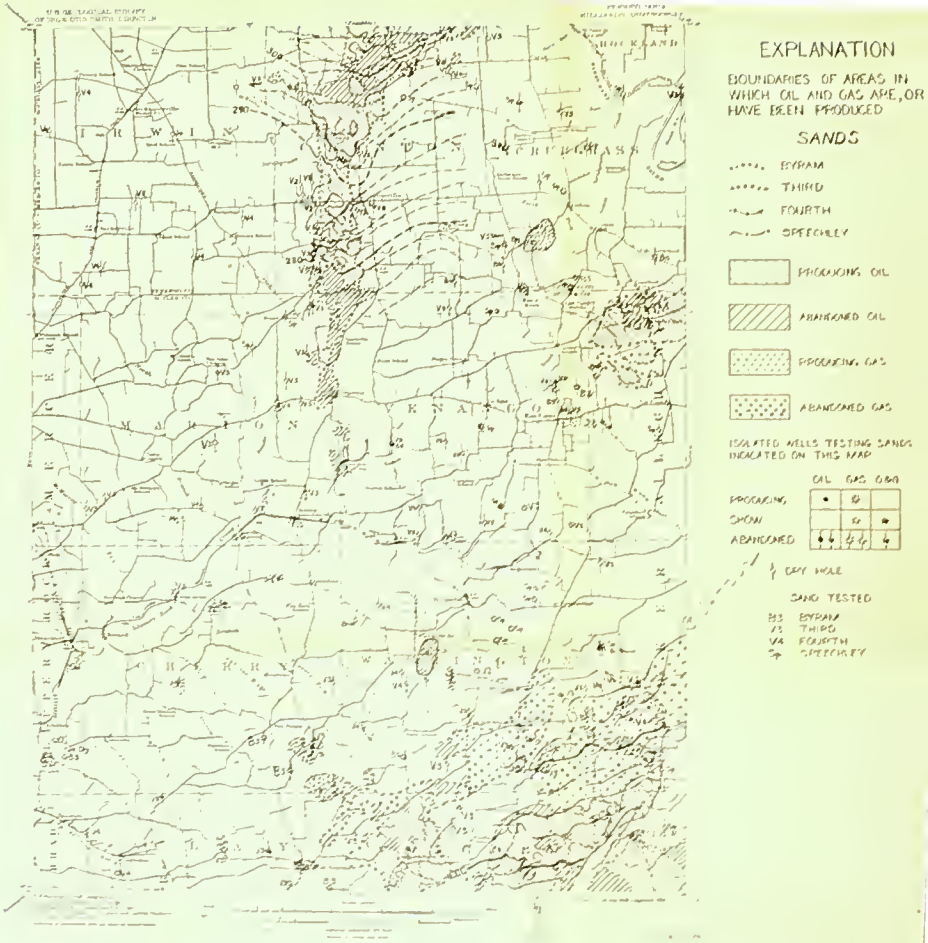

Figure 8. Map of Hilliards Quadrangle showing producing areas of Byram, Third, Fourth and Speechley sands and, locally, the structure of Third and Speechley sands.